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PREFACE

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ABSTRACT

This particular study sought to evaluate the potential emissions impacts of different alcohol blends on a fleet of modern gasoline vehicles. Researchers tested nine vehicles with ten different fuel blend combinations using the Federal Test Procedure and Unified Cycle. The model year of each vehicle ranged from 2007 to 2014 and included four direct injection spark-ignition vehicles and two flexible-fuel vehicles. The results showed several clear trends with increasing levels of alcohol blends for certain pollutants, but not for all. There was a trend for lower carbon monoxide, carbon dioxide, particulate matter mass, particle number, and black carbon emissions, as well as a trend for lower fuel economy with higher alcohol content fuels. For other pollutants, such as total hydrocarbons, non-methane hydrocarbons, methane, and oxides of nitrogen, there were no strong fuel trends; in comparison, total carbonyls showed some trends towards higher emissions for higher alcohol blends. The emissions profiles for the different vehicles also showed differences, with the wall-guided direct injection spark-ignition vehicles showing higher particle matter mass, particle number, and black carbon compared to the port fuel injection and flexible fuel vehicles. The results show that for late model port fuel injection vehicles that alcohol fuels will have impacts similar to those seen for older vehicles, such as carbon monoxide. For other pollutants, the newer vehicles did not show fuel trends. The results also show particle emissions with direct injection spark-ignition vehicles will be an important consideration going into the future. This information will be useful to policymakers as they implement new regulations with respect to renewable fuels.

Keywords: Ethanol, butanol, vehicle emissions, particles, transportation, alternative fuels

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Introduction

Due to concerns about climate change, global energy security, and the decline of world oil resources aggravated by a continuous increase in the demand for fossil fuels, biofuels have been the subject of significant political and scientific attention. Among the different oxygenated biofuels used globally today, ethanol is the most widely employed despite the fact that its usage is somewhat geographically restricted to the United States, Brazil, and Canada. In 2010, the United States Environmental Protection Agency (EPA) implemented the Renewable Fuel Standard (RFS) Program Final Rule. The fuel standard mandated the use of 36 billion gallons of renewable fuels to be blended into transportation fuels by 2022, with ethanol expected to make up the majority of this requirement. As an alternative to ethanol, butanol or butyl alcohol (C_4H_9OH), which is a bio alcohol, can be used in spark ignition (SI) engines without modification. Butanol offers a number of advantages over ethanol for transportation use; butanol is less corrosive than ethanol, has higher energy content than ethanol, and more closely resembles gasoline.

The use of ethanol has been widely investigated for older conventional engines and vehicles. Studies of older vehicles have generally shown reductions in total hydrocarbons (THC), non-methane hydrocarbon (NMHC), and carbon monoxide (CO) emissions with ethanol blends. In contrast, nitrogen oxide (NO_x) emissions have either shown no significant changes or increases with increasing ethanol blends. Studies of newer technology vehicles, specifically spark ignition direct injection (SIDI) vehicles, are more limited, however. Spark ignition direct injection vehicles provide improved fuel economy relative to comparable conventional gasoline vehicles, and are expected to play an important role in meeting more stringent fuel economy requirements. This can lead to a significant increase of in-use (of-road) fleet application in the future. Butanol has also not been studied as extensively as ethanol for either conventional gasoline or spark ignition direct injection vehicles.

Project Purpose

This study evaluated the potential emissions impacts of ten different alcohol fuel blends on a fleet of nine modern gasoline vehicles. A total of 48 different vehicle and fuel combinations were included in the test matrix. The model year for each vehicle ranged from 2007 to 2014 and included four port fuel injection (PFI) vehicles and five SIDI vehicles, two of which were flexible fuel vehicles (FFVs). The ten fuel blends included E10, E15, E20, Bu16, Bu24, Bu32, E51, Bu55, E83, and an E10 and Bu8 fuel blend for FFVs. At each test matrix point, the vehicles were run over three Federal Test Procedure (FTP) cycles and three Unified Cycles. Emissions measurements were made for the typical regulated emissions on each test, including THC, NMHC, NO_x, CO, carbon dioxide (CO_2), and fuel economy. More detailed measurements of the hydrocarbon species were also made, including benzene, toluene, ethyl-benzene, and xylene (BTEX) compounds, 1,3-butadiene, and carbonyls. Additional measurements of particle matter (PM) mass, particle number emissions, particle size distributions, and black carbon were also made.

Project Results

The results showed that alcohol blends continue to have an impact on some pollutant emissions, but not for others, even in the latest generation of vehicle technologies. There were some trends toward lower CO emissions with the higher alcohol fuel blends. For the FFVs, weighted and cold-start CO emissions were lower for E83 than the E10, E51, and Bu55 fuels. These results are consistent with previous studies that have shown reductions in CO with increasing alcohol content due to improved oxidation of the CO as a result of the oxygen content in the fuel. Methane (CH_4) weighted emissions for the FFVs were higher for the higher alcohol blends, with the CH_4 emissions being higher for the E83 blend compared to the E51 and Bu55 blends that were in turn higher than those for the E10. Fuel effects showed mixed results for different vehicles and cycles for THC, NMHC, and NO_x emissions and did not show any statistically significant differences for the weighted emissions for these pollutants.

CO_2 emissions showed some differences between different fuels, but not over all testing conditions. The main effects showed that the highest ethanol blends had lower CO_2 emissions compared to the lower blends, which included the E20 blend for the non-FFVs and the E83 fuel for the FFVs. From a theoretical standpoint, it might be expected that CO_2 emissions would trend with the carbon and hydrogen ratio in the fuel, with lower CO_2 emissions for the higher alcohol blends with lower carbon and hydrogen ratios. This trend was seen for some fuel and cycle combinations, but not for others.

Fuel economy decreased as the alcohol concentration increased, at a level that was approximately proportional to the decrease in energy content of the blend. This trend was consistent for both non-FFVs and FFVs, with the E20, Bu32, and E83 blends showing the lowest fuel economies, although lower fuel economy for the E20 and Bu32 fuels were not found for all cycle phases. The Bu55 fuel also showed a higher fuel economy than the E51 fuel.

Particulate matter (PM) mass and total particle number emissions were higher for the SIDI vehicles, with the exception of the PFI Ford F-150. Overall, cumulative PM emission results showed reductions with higher oxygen levels for the FFVs over the UC, while E20 showed lower PM emissions than the Bu16 and Bu24 fuels for the non-FFVs. For most vehicles, particle number emissions corroborate the PM mass trends. Overall, the black carbon particle results were mixed and did not follow a uniform trend for both test cycles, although there were trends of lower black carbon emissions with increasing alcohol content for different vehicle and cycle combinations. Black carbon emissions were three to seven times higher for the SIDI vehicles compared to PFI vehicles, suggesting that SIDI particulate matter was primarily elemental carbon or soot in nature.

In general, the SIDI vehicles displayed diesel-like particle size distributions that were unimodal in nature. The peak particle number concentrations for the wall-guided SIDI vehicles were substantially higher than those of the spray-guided SIDI vehicle. The particle size distributions showed reduced particle number concentrations with higher oxygen content blends. The majority of vehicles showed marked reductions in the larger accumulation mode particles with E20 and Bu32 blends. The size distributions for the FFVs showed emissions of nucleation mode particles in the size range of 10 to 30 nanometers for most fuels, with the exception of E10 that also showed a higher peak for larger accumulation particles. For the FFVs, the higher oxygen and lower aromatic content E51, E83, and Bu55 systematically showed lower number concentrations of accumulation mode particles and smaller size particles compared to E10.

Total carbonyl emissions for E20 and Bu16 were higher than those of E10. For the non-FFVs, the fuel blends did not show any statistically significant effect on formaldehyde and acetaldehyde emissions. For the FFVs, acetaldehyde emissions increased significantly for the E51 and E83 fuels. For butyraldehyde, increases were found for Bu16 and Bu32 compared to E20 for the non-FFVs, and for Bu55 compared to the E10, E51, and E83 blends for the FFVs.

Toluene was the most abundant BTEX VOC, followed by *m*/*p*-xylene and benzene. For the non-FFVs, benzene and toluene did not show any statistically significant fuel effects, while the Bu32 fuel showed statistically significant reductions in ethylbenzene, *m*/*p*-xylene, and *o*-xylene relative to different combinations of fuels. For the FFVs, E83 and Bu55 showed lower emissions for the various BTEX species compared to E10 and E51. For the FFVs, the Bu55 blend showed a statistically significant increase in 1,3-butadiene compared to E83.

Project Benefits

The results of this work provide important insights into how mixed alcohol blends might impact emissions in the newer generation technology vehicles, and how these impacts might differ from those found in older generation vehicles. In general, the results show that the fuel effects for mixed alcohol blends will likely be less significant in newer port fuel injection vehicles compared to older generation vehicles, with minimal impacts seen for THC, NMHC, and NO_x emissions. Some emissions impacts were still seen with the newer generation port fuel injection vehicles, however, with lower for CO, CO_2, and fuel economy for the higher alcohol blends. The results also show that higher particle emissions will be an important consideration for spark ignition direct injection vehicles, which are rapidly becoming more prevalent in the in-use fleet due to their improved fuel economy benefits. The results show that higher alcohol blends could provide reductions in particle emissions for spark ignition direct injection vehicles, particularly in FFVs that allow for alcohol blends as high as E83. The results of this study provide important information to policy makers about how higher and mixed alcohol blends could impact emissions in newer vehicle technology vehicles as they become more prevalent in the in-use fleet. This will allow for the development of better informed policy that will allow for the increased introduction of renewable fuels into the marketplace while improving or mitigating any environmental impacts. This will provide important benefits to the ratepayer in terms of improved air quality, reductions in greenhouse gas emissions, and reduced dependency on petroleum supplies.

CHAPTER 1: Introduction

Globally, the on-road transportation sector contributes significantly to air pollution and climate change. One of the challenges for the automotive manufacturers is to decrease pollutant emissions, while still meeting strict fuel economy and carbon dioxide (CO_2) emissions requirements. One possible solution is the use of oxygenated biofuels. Biofuels have been the subject of significant political and scientific attention, owing to concerns about climate change, global energy security, and the decline of world oil resources that is aggravated by the continuous increase of the demand for fossil fuels (Brito et al., 2014). Among the different oxygenated biofuels being used globally today, ethanol is the most widely employed, although geographically its usage is somewhat restricted to U.S., Brazil, and Canada (Brito et al., 2009; Strogen et al., 2012). In 2010, the United States (U.S.) Environmental Protection Agency (EPA) implemented the Renewable Fuel Standard (RFS) Program Final Rule, which mandates the use of 36 billion gallons of renewable fuels to be blended into transportation fuel by 2022, with ethanol expected to make up the majority of this requirement (US EPA). The European Union (EU) has also adopted a proposal for a directive on the promotion of the use of biofuels with targets of 5.75 percent by 2010 and 10 percent by 2020 (European Commission, 2009). In addition, fiscal incentives for biofuel usage from EU governments and the rising prices of conventional fossil fuels have triggered a renewed interest in ethanol blends.

Ethanol (C_2H_5OH) is considered to be a green fuel, as it is obtained from biomass sources including corn, sugar cane, sugar beet, sorghum, grain, switch grass, kenaf, cassava, molasses, wheat, and other biomass, as well as many types of cellulose wastes and harvests (Ishizaki and Hasumi, 2014). Use of ethanol as a transportation fuel in the U.S. increased approximately 6-fold over from 2002-2012 from 2 to 13 billion gallons per year (US Energy Information Administration, 2013). Motivations for the increased use of ethanol include energy security, global climate change, as well as economic stimulus and government mandates. In many parts of the U.S., ethanol is currently blended into gasoline at a concentration of 10 percent by volume (E10). Ethanol is also available as E85, which after a recent change in specifications, is allowed to contain as much as 83 percent v/v and as little as 51 percent v/v ethanol. Vehicles designed to use higher blends of ethanol are known as flexible fuel vehicles (FFVs). FFVs have historically been designed for operation on E0/E10 and E85 and are certified for emissions compliance by testing with E0 and E85. There are some component differences between conventional vehicles and FFVs, with the major difference being a fuel sensor that automatically detects the ethanol versus gasoline ratio. This input adjusts the vehicle's fuel injection and ignition timing to compensate for the different fuel mixtures. Other differences include larger diameter injectors for the FFVs, different fuel system plastics and elastomers, and a different engine controller calibration (Zhai et al., 2009; Yanowitz and McCormick, 2009). It is noteworthy that in the U.S., FFVs have been marketed with no added cost differential to the consumer. It is reasonable to assume that the benefits of producing FFVs from a corporate average fuel economy (CAFE) standard point of view more than off-set the added costs associated with the modifications required for FFVs (MIT Energy Institute, 2012). Future blending options for ethanol in gasoline include continuation of low-level blends (E0-E15), greater use of E85 in FFVs, or the use of new mid-level blends (E20-E40) in FFVs or in new vehicles designed with mid-level blend capability.

Addition of ethanol to gasoline comes with some challenges, since ethanol has rather different physical and chemical characteristics than gasoline, which could potentially affect the performance and efficiency of spark-ignition (SI) engines. Adding ethanol into gasoline potentially increases the Reid vapor pressure (RVP) of the blend and alters the distillation properties (Andersen et al., 2010a; Andersen et al., 2010b). Because key volatility properties are changed when ethanol is used, the final gasoline/ethanol blend needs to be formulated to ensure that its properties are within specification for the appropriate geographical region and season. Ethanol is highly water soluble, making it incompatible with the existing infrastructure and pipeline transportation processes due to the risk of water-induced phase separation (Andersen et al., 2012). The net heating value of ethanol is also about one-third less than gasoline on a volume basis. While this difference reduces the volumetric fuel economy (miles per gallon) ethanol can provide a small improvement in the thermal efficiency of engine operation (miles per gallon of gasoline-equivalent) (Yan et al., 2013). Engines designed specifically for use with ethanol can use much higher compression ratios than gasoline engines, resulting in considerable increases in engine efficiency and power for a given engine size (Heywood, 1998). The octane rating of a fuel is a measure of the fuel's ability to resist auto-ignition and knock in a SI engine. Ethanol has both a higher octane rating and a higher heat of vaporization than typical gasoline (Andersen et al., 2010). The higher heat of vaporization of ethanol has a cooling effect that can increase volumetric efficiency and contribute further to knock resistance. For SI direct injection (DI) engines, the increase in heat of vaporization from greater ethanol content leads to additional evaporative cooling of the air-fuel mixture in the cylinder prior to ignition, which inhibits auto-ignition and enables further increases in compression ratio, resulting in even greater overall thermal efficiency. To a lesser extent, the same is true for port fuel injection (PFI) engines, particularly when employing open-valve injection, but much less for PFI with closed-valve injection (Andersen et al., 2012). In addition, the presence of oxygen in the fuel molecule of ethanol enables higher combustion efficiency, while ethanol contains no mono-aromatic or poly-aromatic hydrocarbons, which are considered to be soot precursors.

The drawbacks that have been identified with ethanol use have led to research in the use of higher molecular weight alcohols as gasoline extenders. Currently, an alternative bio-alcohol for use in SI engines without modification is butanol or butyl alcohol (C_4H_9OH) (Alasfour, 1998; Merola et al., 2012; Irimescu, 2012; Szwaja and Naber, 2010). Butanol is a four carbon alcohol compound, which exists as four different chemical isomers depending on the location of hydroxyl group (-OH) and the carbon bond structure. The carbon structure is either straight chain or branched and two isomers exist for each structure. N- or 1-butanol has as a straight chain structure with the alcohol at the terminal carbon. Sec- or 2-butanol is also a straight chain alcohol, but with the OH group at an internal carbon. Iso-butanol is a branched isomer with the OH group at the terminal carbon and tert-butanol refers to the branched isomer with the OH group at an internal carbon (Jin et al., 2011; Xue et al., 2013).

Analogous to ethanol, butanol can be produced from either thermochemical pathways (such as synthesis gas to mixed alcohols) or biochemical pathways (such as fermentation). Historically, butanol has been produced by *Clostridia* via acetone-butanol-ethanol (ABE) fermentation processes. Recently, the use of genetically enhanced bacteria has increased the fermentation process productivity and it is expected that sustainable and cost effective process for butanol production will be realized in the near future (Ranjan and Moholkar, 2012; Swana et al., 2011; Ezeji, 2007). While n-butanol could be an attractive candidate for ethanol replacement because it can be produced via the mature ABE fermentation process, the dramatic energy demand, high water use, and unfavorable process economics have led research towards iso-butanol (Tao et al., 2014). The increased emphasis that butanol is gaining the past five years is reflected by the number of companies that are currently investigating novel alternatives to traditional ABE fermentation, which would enable butanol to be produced on an industrial scale. Two leading technology companies in this area, Gevo and Butamax, have been retrofitting existing ethanol corn plants for the production of iso-butanol. On a regulatory level, ASTM D7862 was announced for blends of butanol with gasoline at 1 to 12.5 percent by volume in automotive SI engines. The specification covers three butanol isomers including 1-butanol, 2-butanol, and 2-methyl-1-propanol (iso-butanol). The specification specifically excludes 2-methyl-2-propanol (tert-butanol).

Butanol offers a number of advantages over ethanol for transportation use. Butanol is less corrosive than ethanol, has a higher energy content than ethanol, and more closely resembles gasoline (Cooney et al., 2009). In comparison to ethanol, butanol has higher tolerance to water contamination, potentially allowing its use in existing distribution pipelines, whereas ethanol must be transported via rail or truck. Butanol has a lower volatility than ethanol and thus less tendency towards cavitation and vapor lock problem (Jin et al., 2011; Baustian and Wolf, 2012). Gasoline vapor pressure is regulated to limit emissions of unburned fuel by evaporation from the fuel tank and engine fuel system. Tao et al. (2013) showed that blending ethanol at levels below 60 volume percent causes a significant increase in vapor pressure. On the other hand, they showed that butanol blends cause the gasoline vapor pressure to go down by about 7 kPa in the 12 percent and 15 percent blend range. They concluded that this was a major advantage of butanol blending that could significantly reduce the cost to produce low vapor pressure gasoline for summer use and allow blending of significantly larger amounts of lower value, high vapor pressure hydrocarbon components in winter months (Tao et al., 2013).

In addition to adding diversity to the fuel pool with alternative fuels, the automotive manufacturers have taken efforts in improving the overall efficiency of gasoline powered passenger cars, which is directly connected to meeting more stringent CO_2 emissions limits. To reach CO_2 targets, different strategies have been studied, including engine downsizing and higher boost pressures in combination with direct gasoline injection. Direct injection spark ignition (SIDI) engines can offer up to a 25 percent improvement in fuel economy compared with PFI SI engines (Zhao et al., 1999). This is mainly achieved through reductions in pumping and heat losses when operated unthrottled at low-mid loads. DI fueling for gasoline engines significantly improves engine power, which allows the engine displacement volume to be reduced for a given application, even while the engine performance improves (Alkidas, 2007).

The penetration of gasoline DI vehicles in the U.S. market is rapidly increasing. It is foreseen that this category of vehicles will dominate the gasoline market, eventually replacing conventional and less efficient PFI vehicles. It is interesting to note that in the U.S., half of all light-duty vehicle certifications for the 2012 model year included gasoline DI engines, reaching approximately 24 percent of the market, up from virtually 0 percent in 2007. This trend is expected to dramatically increase, with a projection of 48 percent and 93 percent, respectively, of all new vehicles having gasoline DI engines by 2016 and 2025 (Gladstein, Neandross, & Associates, 2013).

As previously mentioned, SIDI fueling improves fuel economy and power by directly injecting fuel into the cylinder rather than onto the intake valve in the intake manifold before the air/fuel mixture is drawn into the combustion cylinder. This allows the engine to operate in a diesel-like lean combustion mode at light engine loads or in a stoichiometric combustion mode similar to PFI engines in other situations (Berndorfer et al., 2013). The lean combustion mode is possible because fuel is injected at a position very close to the spark plug, creating a local, stratified, fuel-air mixture that is capable of combusting, even though the overall fuel-air ratio is much too lean for combustion. While operating in the lean combustion mode, the engine does not have to throttle the incoming air as a PFI engine would. Eliminating this throttling can increase fuel economy by 10-20 percent. However, this mode of operation also reduces the amount of time the fuel has to mix with the air, which can increase particulate matter (PM) and ultrafine particle (UFP) formation due to the incomplete combustion caused by heterogeneous mixing. Lean burn SIDI combustion has higher oxides of nitrogen (NO_x) emissions that require the use of sulfur sensitive NO_x control strategies, such as lean NOx traps (LNT), to store the NO_x emissions when the exhaust is oxygen rich and then convert the stored NOx to nitrogen during short periods of controlled over-fueling. This technology has seen limited application on a few vehicles in Europe but is being considered for future U.S. deployment by several manufacturers as a possible approach to help comply with future fuel economy standards (Gladstein, Neandross, & Associates, 2013; Piock et al., 2011; Sementa et al., 2012; Peckham et al., 2011).

While PM emissions from gasoline engines have not received considerable attention, SIDI engines are known to emit more PM than PFI engines (Favre et al., 2013; Mamakos et al., 2013; Liang et al., 2013). The PM characteristics of DI engines in comparison to conventional PFI engines can be mainly attributed to the injection characteristics. More specifically, the more retarded injection timing of SIDI engines in relation to PFI engines leads to relatively poorer mixture preparation. This is due to the fact that less time is available for the vaporization of the fuel and mixture preparation to occur, leading to charge heterogeneity and localized fuel-rich regions in the charge cloud. These locally rich regions result in a high ratio of carbon to oxygen atoms. The excess carbon atoms combine to form aromatic ring structures to nucleate into particles. Further dehydrogenation can lead to fast growth to larger particles (surface growth). In the coagulation phase, larger particles are formed by accumulation governed by physical processes. These larger particles form agglomerates of a non-spherical shape (Whelan et al., 2010; He et al., 2010; Samuel et al., 2010). In studies of gasoline DI vehicles, Aakko and Nylund (2003) found that particle mass emissions for a gasoline DI vehicle were an order of magnitude higher than for a PFI vehicle for the European 70/220/EEC driving cycle. Szybist et al. (2011)

reported that particle number emissions with DI fueling increased by 1-2 orders of magnitude Current production SIDI engines employ wall-guided designs in which the fuel spray is directed from a side-mounted fuel injector towards a contoured piston and then upward toward the spark plug (Giglo et al., 2013). While wall-guided SIDI (WG-SIDI) engines offer advantages over their PFI counterparts, there can be issues relating to fuel preparation including fuel in contact with the cylinder wall surfaces during combustion, which will likely form soot or other semi-volatile compounds because the wall quenches the flame and prevents the complete combustion of the fuel (Piock et al., 2011; Stevens et al., 2001). In addition to soot formation, an increase in total hydrocarbon (THC) emissions is expected due to incomplete evaporation and mixing with air and of adsorption and subsequent desorption of the fuel that, after being trapped in the piston top land crevice, can be dissolved in oil with consequent dilution and loss of lubricant properties (Zhao et al., 1999; Alkidas, 2007; Stevens et al., 2001). Alternative designs to WG-SIDI engines use either homogeneous or stratified-charge spray-guided (SG) SIDI engines. Whilst SG-SIDI engines can be operated in a homogeneous charge mode only, the greatest fuel economy benefit is achieved with unthrottled lean stratified operation. For the SG-SIDI configuration, the fuel injector and spark plug electrodes are closely spaced in the center of the chamber. The fuel injector confines the fuel spray such that it does not contact the cylinder walls, improving mixing and reducing soot formation and THC emissions (Park et al., 2012; Oh and Bae, 2013; Dahms et al., 2011).compared to PFI fueling.

The use of ethanol has been widely investigated for SI-PFI, SIDI, and FFV engines and vehicles (Kapus et al., 2007; Liu et al., 2012; US EPA, 2013). Studies of older PFI vehicles have generally shown reductions in THC, non-methane hydrocarbon (NMHC), carbon monoxide (CO) emissions with ethanol blends, while nitrogen oxide (NOx) emissions have either shown no significant changes or increases with increasing ethanol blends (Knoll et al., 2009; Durbin et al., 2007). Karavalakis et al. (2012) found that THC, NMHC, and CO emissions were lower with ethanol blends for PFI vehicles, while NO_x emissions showed some increases with increasing ethanol content in gasoline. These trends were more consistent for the older SI-PFI vehicles in the study. They also found higher acetaldehyde and some higher formaldehyde emissions with the ethanol blends, whereas the toxic compounds of benzene and 1,3-butadiene were lower. A recent study by Bielaczyc et al. (2013) showed small reductions in THC, CO, and NOx emissions from SI-PFI vehicles with higher ethanol blends over the New European Driving Cycle (NEDC). They also found that the addition of ethanol caused a decrease in the number of particles and a significant reduction in particulate matter (PM) mass emissions. Maricq et al. (2012) showed small benefits in PM mass and particle number emissions as the ethanol level in gasoline increased from 0 to 20 percent when they tested a SI-DI turbocharged vehicle with two engine calibrations. They also found higher reductions in both PM mass and particle number emissions with ethanol contents >30 percent. Clairotte et al. (2013) showed that a flex fuel vehicle fitted with a SIDI engine reduced CO, CO_2, and NOx emissions with higher ethanol blends, but led to higher emissions of THC, non-methane hydrocarbons (NMHC), formaldehyde, and acetaldehyde. Higher THC emissions with higher ethanol blends were also seen in other studies employing SG-SIDI engines. In addition, Graham et al. (2008) showed lower CO and non-methane organic gases (NMOG) emissions from a SIDI vehicle with E10 and E20 blends relative to gasoline. They also showed increases in formaldehyde, 1,3-butadiene, and benzene emissions with ethanol use. Yanowitz et al. (2013) found reductions in NO_x, CO, CO_2, and acetone emissions, as well as increases in emissions of ethanol, acetaldehyde, and formaldehyde, when they tested FFVs on E40. In a recent study, Hubbard et al. (2014) tested a 2006 model year FFV on E10, E10, E20, E40, E55, and E80. They found higher tailpipe ethanol, formaldehyde, acetaldehyde, methane, and ammonia emissions as ethanol content increased, while NO_x and NMHC emissions decreased. He et al. (2012) investigated the effects of certification gasoline and E20 on particle number emissions from a WG-SIDI engine. They showed that at low and medium loads E20 reduces particle number emissions, while at high engine loads E20 usually produces higher particle number emissions than E0. Higher PM mass and particle number emissions with increasing ethanol concentration have been reported in another study conducted on a SG-SIDI engine (Chen et al., 2012). Finally, Storey et al. (2010) reported that NO_x, CO, formaldehyde, and benzaldehyde emissions decreased with increased ethanol concentration, while some increases were seen in THC and acetaldehyde emissions when they tested a turbocharged DI vehicle over the Federal Test Procedure (FTP) cycle and the more aggressive US06 cycle. They also showed reduced PM mass and particle number emissions with ethanol blends.

Butanol has not been studied as extensively as ethanol. An earlier study of butanol usage as an engine fuel showed that it was more prone to generate combustion knock than gasoline (Yacoub et al., 1998). Gautam et al. (2000) found that butanol blends resulted in lower CO_2, CO, and NO_x emissions compared to gasoline. Dernotte et al. (2010) assessed different butanol-gasoline blends at different engine loads, spark timings, and equivalence ratios in a SI-PFI engine. They found some THC reductions with butanol, while no significant differences were seen in NO_x emissions. Schulz and Clark (2011) carried out a study comparing various ethanol blends and a 16percent butanol blend using six modern technology vehicles over the FTP cycle. They found a limited number of statistically significant differences between the fuels tested, however, a decreasing trend in CO and formaldehyde emissions was observed with the butanol blend compared to gasoline. Ratcliff et al. (2013) studied the effect of four alcohol blends, including butanol, on the regulated and toxic emissions from a PFI vehicle. They found large increases in formaldehyde and butyraldehyde emissions with iso-butanol blends compared to gasoline. With respect to SI-DI engines, Wallner and Frazee (2010) found that NO_x, CO, and THC emissions were lower with increasing butanol content in gasoline, while some increases were seen for formaldehyde and acetaldehyde emissions when they utilized n-butanol and iso-butanol as blending agents with gasoline. In a similar study, the same authors showed lower volumetric fuel consumption and lower NO_x emissions for butanol compared to ethanol blends (Wallner et al., 2009). He et al. (2010) studied the impacts of particle number emissions on a 12 percent iso-butanol blend in a turbocharged WG-SIDI engine under various operating conditions. They showed that the butanol blend reduced particle emissions in all conditions compared to E0.

The goal of this study is to evaluate the potential emissions impacts of different alcohol blends on a fleet of modern gasoline vehicles. A total of 9 vehicles were tested, including 4 SIDI vehicles and 2 FFVs. A total of 10 fuel blends were tested, included E10, E15, E20, Bu16, Bu24, Bu32, an E10/Bu8 blend, E51, Bu55, and E83. For the vehicle emissions testing, the text matrix included 48 different vehicle/fuel combinations. At each test matrix point, the vehicles were run over 3 Federal Test Procedure (FTP) cycles and 3 Unified Cycles. Emissions measurements were made for the typical regulated emissions on each test, including THC, NMHC, NO_x, CO, CO_2, and fuel economy. Over the FTP cycles for each of the 48 test matrix points, more detailed measurements of the hydrocarbon species, including BTEX [benzene, toluene, ethyl-benzene, and xylene] compounds, 1,3-butadiene, and carbonyls were also made. Additional measurements of PM mass, particle number emissions, particle size distributions, and black carbon were also made.

CHAPTER 2:
Experimental Procedures

A total of ten fuels were employed in this study. The fuel test matrix included an E10 fuel (10 percent ethanol and 90 percent gasoline), which served as the baseline fuel for this study, and four more ethanol blends, namely E15, E20, E51, and E83. For this study, iso-butanol was blended with gasoline at proportions of 16 percent (Bu16), 24 percent (Bu24), 32 percent (Bu32), and 55 percent (Bu55) by volume, which, are the equivalents of E10, E15, E20, and E83, respectively, based on the oxygen content. In addition, an alcohol mixture consisting of 10 percent ethanol and 8 percent iso-butanol (E10/Bu8) was used. This mixed alcohol formulation was equivalent to E15 based on the oxygen content. All fuels were custom blended to match the oxygen contents, maintain the Reid vapor pressure (RVP) within certain limits (6.4-7.2 psi), and match the fuel volatility properties, except the E10/Bu8 fuel that was a 50/50 splash blend of the E20 and Bu16 fuels. Some key properties showing that the test fuels of this study were match-blended are illustrated in Figure 1and Figure 2. The main physicochemical properties of the ethanol and butanol test fuels are presented in Table 1 and Table 2, respectively.

Figure 1: Distillation Characteristics for the Ethanol and Iso-Butanol Blends

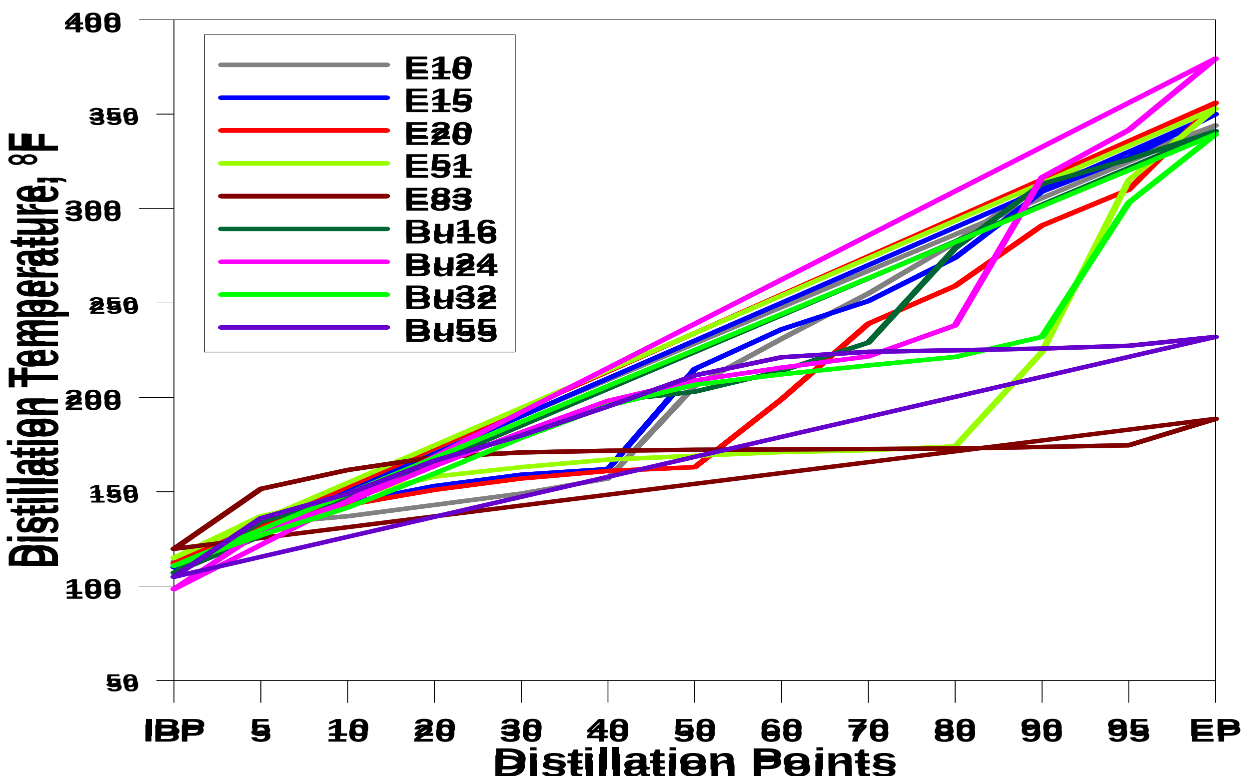


Figure 2: Total Oxygen, Aromatics, and Multi-Substituted Aromatics Contents of the Test Alcohol Blends

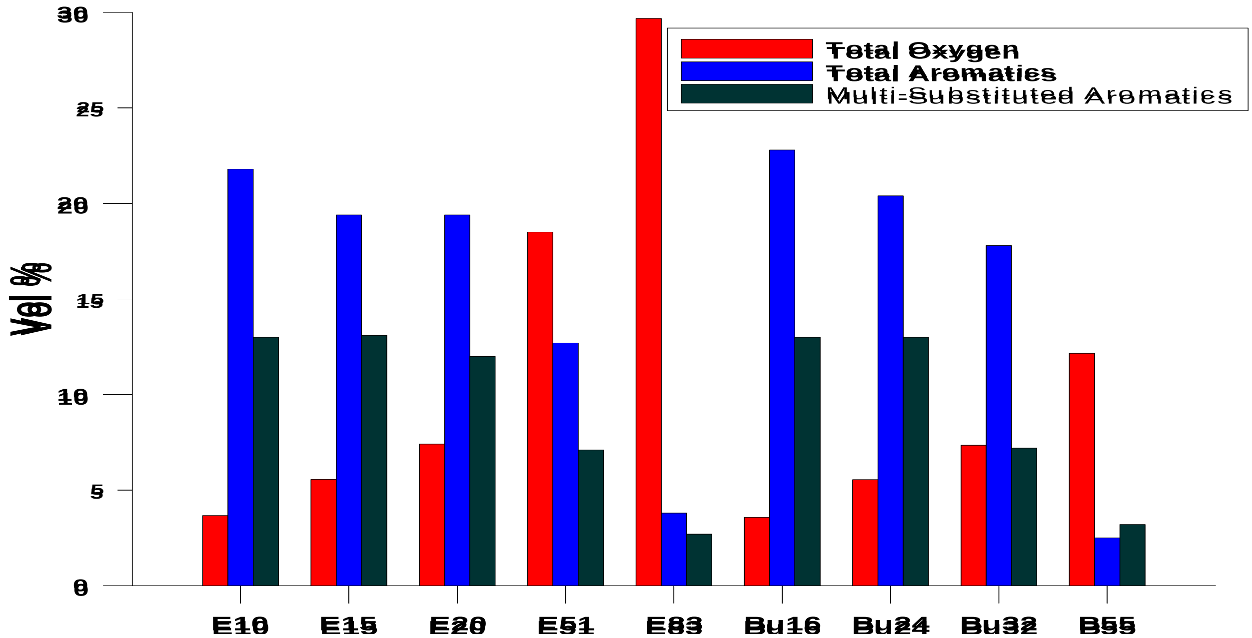


Table 1: Test Fuel Properties for the Ethanol Blends

Property	E10	E15	E20	E51	E83	Test Method
Distillation- IBF (°F)	113	110	112	115	119.7	ASTM D86
10 (°F)	137	144	143	147	162.5	
50 (°F)	206	215	163	169	172.2	
90 (°F)	313	309	291	224	173.7	
EP (°F)	344	350	356	353	188.6	
Gravity (°API)	57.8	57.8	57.6	52.4	48.9	ASTM D4052
Reid Vapor Pressure (psi)	7.0	6.91	7.2	7.1	6.15	ASTM D5191
Ethanol/ Iso- Butanol Content (vol %)	9.96	15.08	20.10	50.89	83.24	ASTM D4815
Total Oxygen (wt %)	3.67	5.56	7.41	18.50	29.68	ASTM D4815
Carbon (wt fraction)	82.54	80.70	78.89	68.28	0.5705	ASTM D5291
Hydrogen (wt fraction)	13.85	13.96	13.70	13.43	0.1327	ASTM D5291
Sulfur (ppm wt)	10	9	7.56	7	3	ASTM D5353
Aromatics (vol %)	21.8	19.4	19.4	12.7	3.8	ASTM D5580
Olefins (vol %)	5.1	4.5	4.5	2.3	1	ASTM D6550

Property	E10	E15	E20	E51	E83	Test Method
RON	92.9	94.6	94.5	105	106	ASTM D2699
MON	84.7	86.1	85.0	89	90.5	ASTM D2700
Octane ((RON+ MON)/2)	88.8	90.4	89.8	97	98.3	ASTM D2699/2700
Net Heat of Combustion (BTU/Ib)	18056	17515	17029	14992	11540	ASTM D240

Table 2: Test Fuel Properties for the Iso-Butanol Blends

Property	Bu16	Bu24	BU32	Bu55	Test Method
Distillation- IBF (°F)	107	98	111	104.9	ASTM D86
10 (°F)	148	145	142	148.9	
50 (°F)	203	209	207	211.6	
90 (°F)	313	317	232	225.8	
EP (°F)	341	379	339	232	
Gravity (°API)	56.3	56.7	55.9	53.7	ASTM D4052
Reid Vapor Pressure (psi)	7.1	6.9	7.1	7.0	ASTM D5191
Ethanol/ Iso- Butanol Content (vol %)	15.79	24.01	31.86	53.46	ASTM D4815
Total Oxygen (wt %)	3.58	5.55	7.35	12.16	ASTM D4815
Carbon (wt fraction)	82.79	80.95	79.09	73.61	ASTM D5291
Hydrogen (wt fraction)	13.65	13.66	13.56	14.23	ASTM D5291
Sulfur (ppm wt)	9	8	7	1	ASTM D5353
Aromatics (vol %)	22.8	20.4	17.8	2.5	ASTM D5580
Olefins (vol %)	5.6	5.1	3.6	1.1	ASTM D6550

Property	Bu16	Bu24	BU32	Bu55	Test Method
RON	93.0	96.9	97.0	99.6	ASTM D2699
MON	88.5	91.6	91.8	93.6	ASTM D2699/2700
Octane ((RON+ MON)/2)	88.5	91.6	91.8	93.6	ASTM D2699/2700
Net Heat of Combustion (BTU/Ib)	17637	17648	17.339	16313	ASTM D240

2.1 Test Vehicles

This program utilized nine light-duty gasoline vehicles of different designs (passenger cars and trucks). The vehicles included a 2007 model year (MY) Honda Civic equipped with a 1.8L, 4 cylinder PFI engine, a 2007 MY Dodge Ram equipped with a 5.7 L, 8 cylinder PFI engine, a 2012 MY Toyota Camry equipped with a 2.5L, 4 cylinder PFI engine, a 2012 MY Kia Optima equipped with a 2.4 L, 4 cylinders SIDI engine, a 2012 MY Chevrolet Impala equipped with a 3.6 L, 6 cylinders SIDI engine, a 2012 MY Mazda3 equipped with a 2.0 L, 4 cylinders SIDI engine, a 2012 MY Mercedes Benz equipped with a 3.5 L, 6 cylinders SIDI engine, a 2013 MY Ford F-150 equipped with a 3.7 L, 6 cylinders PFI engine, and a 2014 MY Chevrolet Silverado equipped with a 5.3 L, 8 cylinders SIDI engine. All vehicles were operated stoichiometrically and were equipped with three-way catalysts (TWC). For the DI engines, the 2012 Kia Optima, 2012 Chevrolet Impala, 2012 Mazda3, and 2014 Chevrolet Silverado used a wall-guided design, while the 2012 Mercedes Benz used a spray-guided design. The Honda Civic, Dodge Ram, Toyota Camry, Kia Optima, Chevrolet Impala, Mazda3, Mercedes Benz, Ford F-150, and Chevrolet Silverado had 29,000 miles, 52400 miles, 13,500, 11,824, 25,372, 18,851, 10,996, 13,687, and 2,649 miles, respectively, at the start of the test campaign.

The Honda Civic was certified to the U.S. Tier 2 Bin 5/ California Low Emission Vehicle (LEV) II, Ultra Low Emission Vehicle (ULEV) emissions standards, the Dodge Ram was certified to the U.S. Tier 2 Bin 4/LEV II emissions standards, the Toyota Camry met the U.S. Tier 2 Bin 5/PZEV emissions standards, the Kia Optima was certified to the Federal Tier 2, Bin 2 emission standards, the Chevrolet Impala, Mazda3, and Mercedes Benz, were certified to California LEV II, Super ultra-low emission vehicle (SULEV) emission standards, and the Ford F-150 and Chevrolet Silverado were certified to California LEV II, ULEV emission standards. The technical characteristics of all vehicles are described in Table 3. It should be noted that not every vehicle was tested on all fuels. Only the Toyota Camry and the Kia Optima were tested on the E10/Bu8 mixture. The higher ethanol (E55 and E83) and iso-butanol (Bu55) blends were only tested on the FFVs, namely the Ford F-150 and the Chevrolet Silverado.

Table 3: Test Vehicle Specifications

Model	MY	Displacement (L)	Config	Standard	Injection System	Mileage
Honda Civic[a]	2007	1.8	I4	PFI	Tier 2 Bin 5/ULEV II	29,000
Dodge Ram[b]	2007	5.7	V8	PFI	Tier 2 Bin 4/LEV II	52,400
Toyota Camry[α]	2012	2.5	I4	PFI	Tier 2 Bin 5/PZEV	13,500
Kia Optima[α]	2012	2.4	I4	Wall-guided DI	Tier 2, Bin 2	11,824
Chevrolet Impala[α]	2012	3.6	V6	Wall-guided DI	LEV II, SULEV	25,372
Mazda3[α]	2012	2.0	I4	Wall-guided DI	LEV II, SULEV	18,851
Mercedes Benz[α]	2012	3.5	V6	Spray-guided DI	LEV II, SULEV	10,996
Ford F-150[b, c]	2013	3.7	V6	PFI	LEV II, ULEV	13,687
Chevrolet Silverado[b, c]	2014	5.3	V8	Wall-guided DI	LEV II, ULEV	2,649

[α] Passenger cars; [b] Light-duty trucks; [c] Flexible Fuel Vehicles (FFVs)

2.2 Test Matrix

The test matrix included a total of 48 vehicle/fuel combinations. The sequence of test fuels differed for the conventional/GDI vehicles, as compared to the FFVs. The test matrix is provided in Table 4 for the testing of a broader range of alcohol blends and alcohol types.

Table 4: Test Matrix

Vehicle	E10	E15	E20	But16	But24	But32	E10/But8	PM sampling
2007 Honda Civic	x	x	x	x				
2007 Dodge Ram	x	x	x	x				
2012 Toyota Camry	x	x	x	x	x	x	x	
2012 Kia Optima	x	x	x	x	x	x	x	
2012 Chevrolet Impala	x	x	x	x	x	x		
2012 Mazda3	x	x	x	x	x	x		
2012 Mercedes Benzz	x	x	x	x	x	x		x
	E10	**E51**	**E83**	**E85**				
2013 Ford F-150	x	x	x	x				x
2014 Chevrolet Silverado	x	x	x	x				x

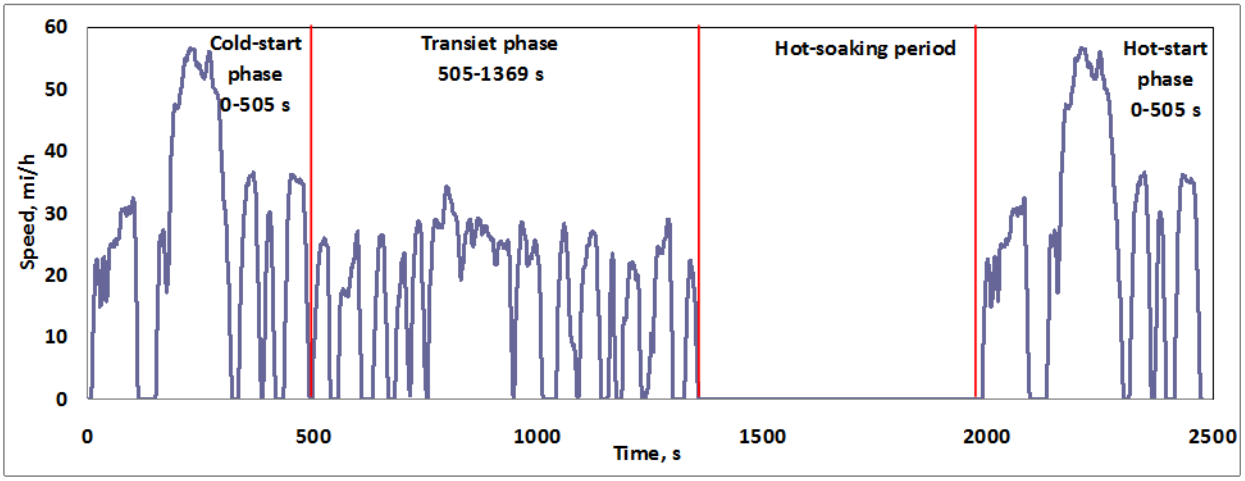
2.3 Test Cycles and Test Sequence

Each vehicle was tested on each fuel over three Federal Test Procedure (FTP) and three Unified Cycle (UC) tests. The six tests on a particular fuel were conducted sequentially once the vehicle was changed to operate on that fuel, and the fuel was not changed to another fuel during this time.

The FTP is the primary emission certification driving cycle of light-duty vehicles in the U.S. The FTP cycle consists of three segments or bags representing a cold-start transient phase, a stabilized phase, and a hot-start transient phase. The cold-start phase (bag 1) has duration of 505 seconds. The second portion or stabilized phase (bag 2) is a transient section from 506 seconds to the end at 1369 seconds. The vehicle is turned off for a period of 10 minutes at the conclusion of the stabilized phase and prior to starting the hot-start transient phase. The cycle covers a total distance of 11.04 miles with an average speed of 21.2 mi/hr. The emissions result is a weighted average where the cold-start and transient is weighted at 43 percent and the hot-start and transient is weighted the 57 percent. A speed-time trace for the FTP is provided in Figure 3. The

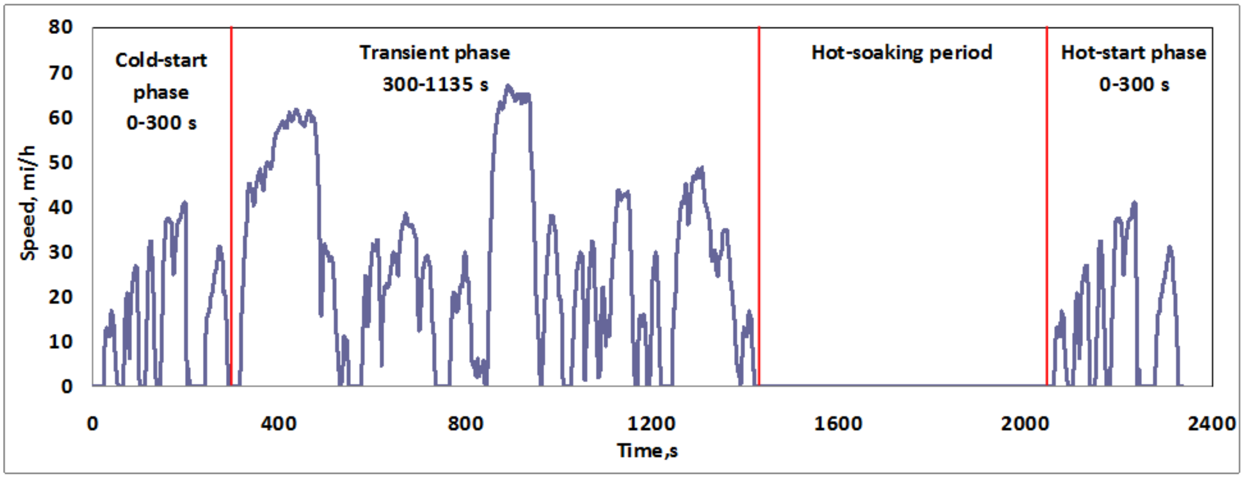
FTP speed-time trace is relatively mild and compared to typical in-use driving, and it does not include very aggressive accelerations or high speeds.

Figure 3: FTP Cycle



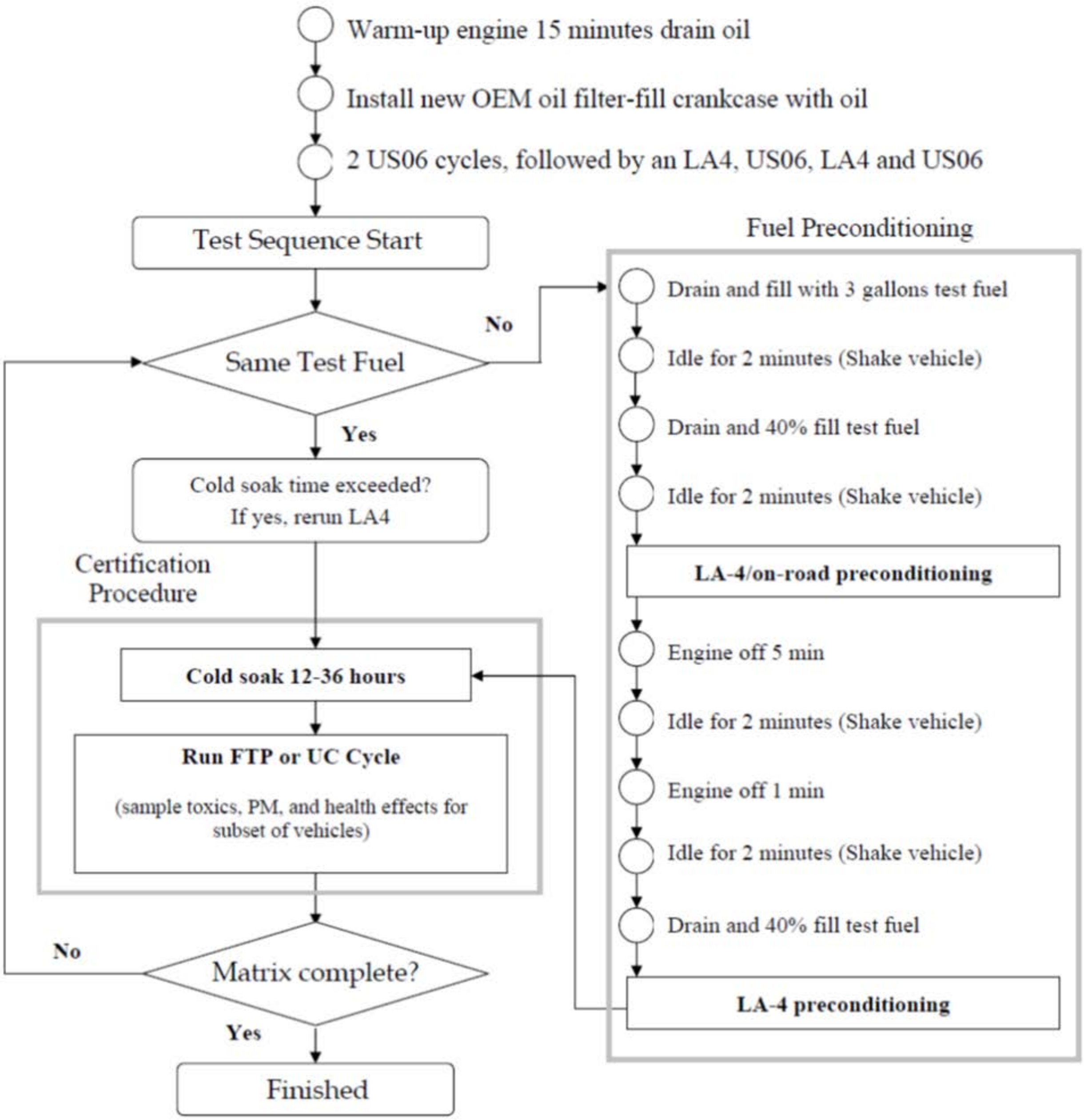
The Unified Cycle (UC), shown in Figure 4, is a dynamometer driving schedule for light-duty vehicles that was developed by the California Air Resources Board. The UC test has three segments or a three-bag structure, similar to the FTP, but it is a more aggressive driving cycle. It has a higher average speed, higher acceleration rates, fewer stops per mile, and less idle time than the FTP. The UC test is run in the following manner: the cold-start phase (bag 1) and transient phase (bag 2) are run consecutively, followed by a ten minute hot soak, and then the hot-start phase (Bag 3), which is has the same speed-time trace as Bag 1, is run. Overall cycle emissions for this report were calculated using the same weighting as for the FTP, but using the actual mileage from the individual UC bags.

Figure 4: Unified Cycle



Prior to testing any particular vehicle, an extensive preconditioning procedure was followed regarding oil and fuel changes. Figure 5 summarizes the oil and fuel conditioning procedure in a flow chart. Prior to beginning testing on a vehicle, its lubricant oil was changed. Following the oil change, the vehicle was conditioned on the oil over two US06 cycles, followed by an LA4 and a US06 cycle sequence repeated twice (i.e., a total of 4 US06 cycles and 2 LA4s). The vehicle fuel preconditioning procedure incorporated multiple fuel drains and fills to ensure complete changeover of the fuel and to minimize or eliminate carryover effects between test fuels. The preconditioning procedure was similar to that specified in the Code of Federal Regulations (40 CFR 86.132-96). This drain and fill sequence included two drain and 40 percent fills and one drain and 3 gallon fill. After the drain and 3 gallon fill, and the first drain and 40 percent fill, the vehicle was then conditioned either on the road or on the dynamometer over the Urban Dynamometer Driving Schedule (UDDS)/LA4, or the first two bags of the FTP. The on-road course was designed to simulate the LA4 portion of the FTP in terms of typical speeds as well as number of stops. In between drain and fill and preconditioning cycles, the vehicle was idled one or two times for two minutes with the vehicle being rocked back and forth. Following the first LA4, a sequence of engine off and idles was performed along with a drain and 40 percent fill. After this sequence, the vehicle was given its final preconditioning LA4 on the dynamometer, and then placed into cold soak overnight prior to performing the FTP or UC test.

Figure 5: Flow Chart for Test and Preconditioning Sequence



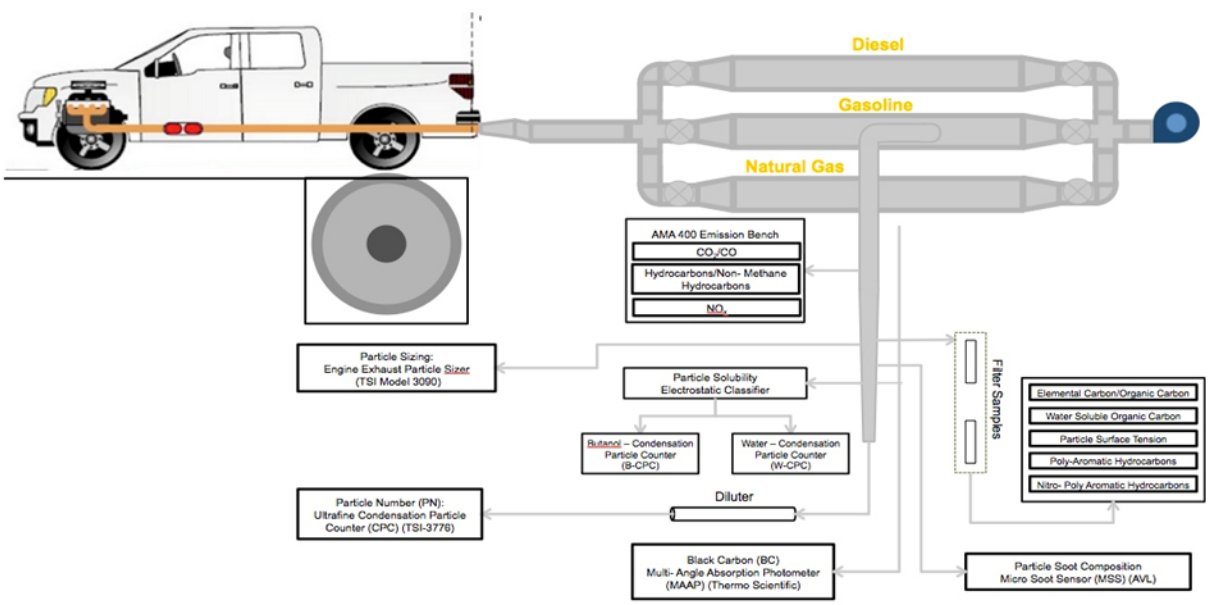
2.4 Emissions Testing and Measurements

All tests were conducted in CE-CERT's Vehicle Emissions Research Laboratory (VERL), which is equipped with a Burke E. Porter 48-inch single-roll electric dynamometer. A typical setup for the test vehicles on the chassis dynamometer is shown in Figure 6. A Pierburg Positive Displacement Pump-Constant Volume Sampling (PDP-CVS) system was used to obtain certification-quality emissions measurements. For all tests, standard bag measurements were obtained for THC, CO, NO_x, NMHC, and CO_2. NMHC was determined from the combined results from the THC analyzer and a separate CH_4 analyzer. Bag measurements were made with a Pierburg AMA-4000 bench.

Figure 6: Typical Setup of Test Vehicles on the Chassis Dynamometer

In addition to the standard regulated emissions, additional measurements were made of a number of other emissions species. This included carbonyls, benzene, toluene, ethylbenzene, and xylenes (BTEX), PM mass, particle number, particle size distributions, and black carbon. A schematic of the full experimental setup is provided in Figure 7. For a subset of 3 vehicles and 4 fuels, or 12 test matrix points, additional tests will also be performed to characterize the PM and health effects. These tests included polycyclic aromatic hydrocarbons (PAHs), organic and elemental carbon, ions, and trace elements, and three chemical assays to measure the prooxidant content, the metal based prooxidant content, and the electrophile content of PM. These analyses are part of a separate contract under funding by the South Coast Air Quality Management District (SCAQMD) and will be reported separately.

Figure 7: Schematic of Experimental Setup



Samples for carbonyl analysis were collected on 2,4-dinitrophenylhydrazine (DNPH) coated silica cartridges (Waters Corp., Milford, MA). Sampled cartridges were extracted using 5 mL of acetonitrile and injected into an Agilent 1200 series high performance liquid chromatograph (HPLC) equipped with a variable wavelength detector. The column used was a 5 μm Deltabond AK resolution (200cm x 4.6mm ID). The HPLC sample injection and operating conditions were set up according to the specifications of the SAE 930142HP protocol (Siegl et al., 1993).

Carbotrap adsorption tubes consisting of multi-beds, including a molecular sieve, activated charcoal, and carbotrap resin. An Agilent 6890 GC with a FID maintained at 300 °C was used to measure volatile organic compounds. A Gerstel TDS thermal adsorption unit was used for sample injection. This unit ramps the temperature from 30 °C to 380 °C at a rate of 6 °C per minute to desorb the sample from the tubes. A 60 m x 0.32 mm HP-1 column was used. For these analyses, the GC column and operating conditions were set up according to the specifications of SAE 930142HP Method-2 for C_4-C_{12} hydrocarbons. It should be noted that the amount of sample that is collected and injected into the GC using the Carbotrap absorption tubes is considerably greater than what can be achieved using Tedlar bag samples, since the absorption tubes are sampled over the duration of the test cycle, and hence allow for much large equivalent volume of sample to be injected into the GC. Thus, the detection limits with the thermal desorption tubes are improved by several orders of magnitude compared to levels achieved in earlier Auto/Oil programs.

PM measurements were made on both a mass and number basis. PM mass samples were collected cumulatively over the entire FTP and UC cycles, with one sample collected for each test. Total PM mass determinations were collected using 47 mm Teflon® filters and measured with a 1065-compliant microbalance in a temperature and humidity controlled clean chamber. Particle number measurements were made with a TSI model 3772 condensation particle counter (CPC) for the Honda Civic and Dodge Ram and a TSI model 3776 CPC for the Toyota Camry, Kia Optima, Chevrolet Impala, Mazda3, Mercedes Benz, Ford F-150, and Chevrolet Silverado. The TSI 3772 was replaced by the TSI 3776, since the 3776 CPC has a lower cut point, 2.5 nm compared to 10 nm for the TSI 3722, and also provides a real-time coincidence correction up to 300,000 particles per cm^3. An ejector diluter was used to collect samples from the CVS tunnel.

Real-time particle size distributions were also obtained for some fuel blends using an Engine Exhaust Particle Sizer (EEPS) spectrometer. The EEPS was used to obtain real time second-by-second size distributions between 5.6 to 560 nm. Particles were sampled at a flow rate of 10 lpm, which is considered to be high enough to minimize diffusional losses. They were then charged with a corona charger and sized based on their electrical mobility in an electrical field. Concentrations were determined through the use of multiple electrometers.

2.5 Statistical Analysis

Statistical analyses for each pollutant were run using the Mixed procedure in PC/SAS from SAS Institute, Inc. The mixed models were performed for each pollutant to determine the statistical significance of any fuels effects. The fuel type and the test type (i.e., FTP or UC) were included in the models as fixed effects, the vehicle was a random effect. The statistical analyses were run separately for the seven non-FFVs and the two FFVs, because they were tested on a different set of fuels.

Analyses were run using the logarithmic transform of the data, as previous studies have shown that the emissions standard deviation is relatively constant as a percentage of the emission level. For example, vehicles with higher emission levels will tend to have a higher variability on an absolute basis than those with lower emissions levels. The normality of residuals was checked in the models for all regulated and toxic emissions to determine if a transformation was necessary. Examination of the current data revealed that this relationship between the emissions level and variability held true even for the very low emitting vehicles. The fuel economy was analyzed in the inverse scale (i.e., gallons/mile). For emissions components that included zeros for individual bags or weighted emissions, a small constant was added prior to taking the logarithm to allow the analyses to be done in the logarithm scale. Any added constants were selected to be as small as possible, and in all cases did not exceed the background levels.

ANOVA results were considered to be statistically significant for $p \leq 0.05$ and marginally statistically significant for cases where $0.05 < p \leq 0.1$. Pairwise comparisons were made using a least squares means test. The results from the ln or inverse models were "back transformed" to provide least square means for all pollutants on each fuel. This provides an arithmetic measure to evaluate the magnitude of any statistically significant effects. Any constants added to facilitate the analysis in logarithm scale were subsequently subtracted from the least square means once the back transformation to the arithmetic scale was made.

CHAPTER 3: Light-Duty Vehicle Chassis Dynamometer Testing Results

The emissions results are presented in the following section. The figures for each emissions component show the results for each vehicle/fuel/cycle combination based on the average of the tests conducted on that particular test combination. The error bars on the figures are the standard deviation over all tests for each test combination. The statistical analysis results for either the seven non-FFVs or the two FFVs are based on the methods described in Section 2.6. Note that since the statistical analyses were run with test type as a fixed effect, the percent differences provided in the text represent percentage differences based on the combined results of the FTP and UC testing, unless the ANOVA showed that there was a statistically significant fuel-test cycle interaction. In the cases where a statistically significant fuel-test cycle interaction was found, indicating that the fuel effects were different for the two cycles at a statistically significant level, the LSMs were determined separately and reported separately for the FTP and the UC. In additional to the fleetwide statistical analysis results, in some cases, additional fuel trends for individual vehicles are also discussed where the comparisons are noteworthy. The results for all emissions tests on the test vehicles are provided in Appendix A and the results for the statistical analyses are provided in Appendix B.

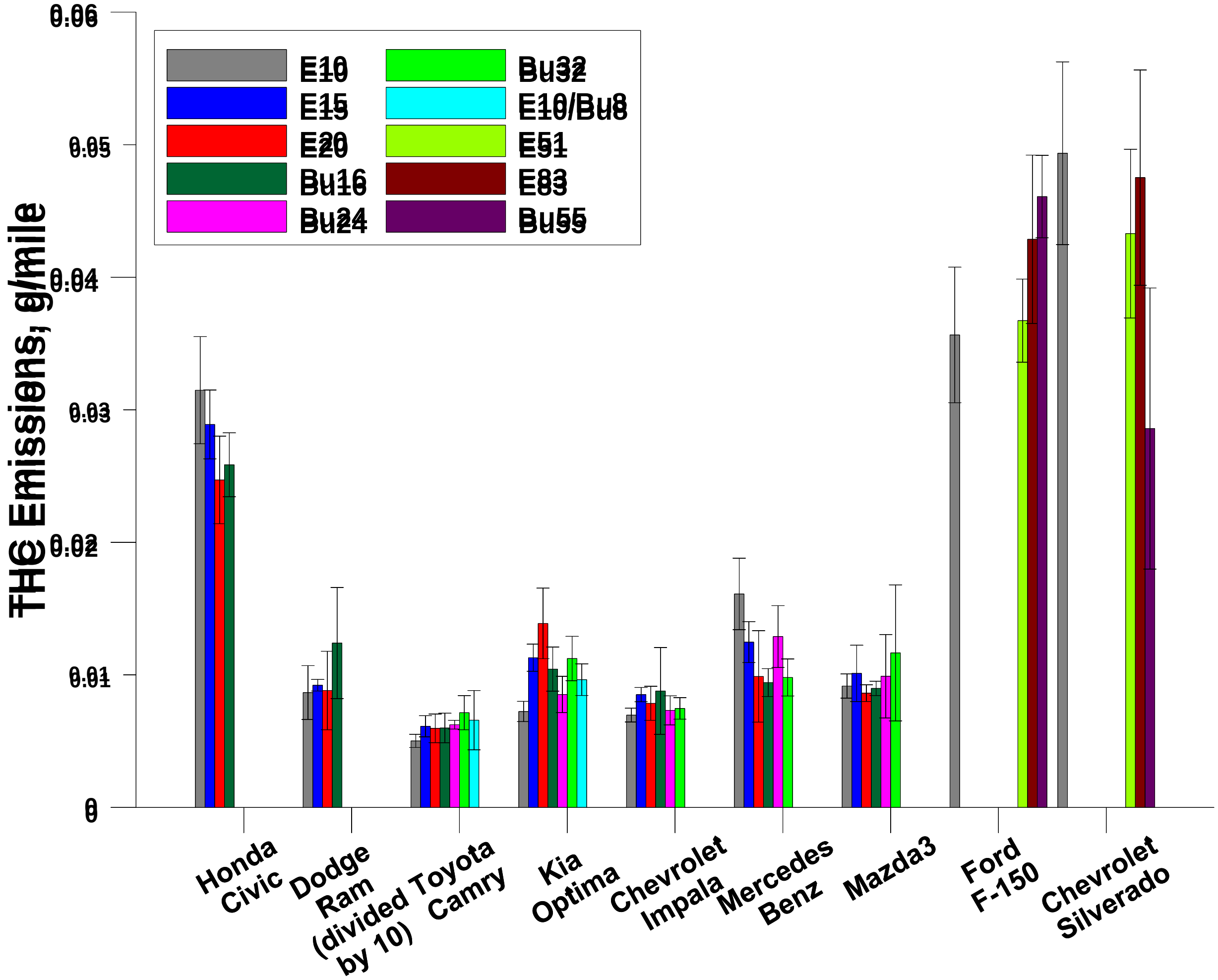
3.1 THC, NMHC, and CH_4 Emissions

THC emissions for all vehicle/fuel combinations over the FTP and UC test cycles are shown in Figure 8 and Figure 9, respectively. In general, THC emissions were found at low levels for all nine vehicles for both test cycles, ranging from 0.005 to 0.124 g/mile for the FTP and 0.005 to 0.093 g/mile for the UC. Higher THC emissions were observed for the older model PFI fueled Honda Civic and Dodge Ram vehicles and both FFVs compared to the other vehicles. Overall, the largest portion of THC emissions was emitted during the first 200-300 seconds of the FTP and UC cycles (bag 1) when the engine was cold. Cold-start THC emissions ranged from 0.098-0.140 g/mile and 0.281-0.335 g/mile for the Honda Civic, 0.227-0.675 g/mile and 0.536-1.135 g/mile for the Dodge Ram, 0.014-0.028 g/mile and 0.043-0.102 g/mile for the Toyota Camry, 0.026-0.068 g/mile and 0.072-0.394 g/mile for the Kia Optima, 0.020-0.059 g/mile and 0.061-0.106 g/mile for the Chevrolet Impala, 0.030-0.064 g/mile and 0.087-0.225 g/mile for the Mercedes Benz, 0.025-0.039 g/mile and 0.080-0.143 g/mile for the Mazda 3, 0.115-0.213 g/mile and 0.156-0.497 g/mile for the Ford F-150, and 0.091-0.252 g/mile and 0.236-0.786 g/mile for the Chevrolet Silverado over the FTP and UC tests cycles, respectively. The higher cold-start THC emissions can be attributed to incomplete combustion products from the fuel enrichment during start up and from the reduced catalyst efficiency, as the catalyst is below its light-off temperature during a good portion of the cold-start phase. The cold start emissions for the UC are higher than those for the FTP because bag 1 for the UC cycle is shorter, and hence the fraction of time when the catalyst is below its light-off temperature is greater for the UC bag 1. THC emissions for the hot-running and hot-start phases were practically eliminated, as the TWC was highly efficient in oxidizing the hydrocarbon fuel fractions once it had reached its light-off temperature. Higher cylinder surface temperatures during the hot-running and hot-start phases would also aid in better fuel vaporization and avoiding pool fires.

There were no consistent fuel effects for the weighted THC emissions over the conventional vehicle fleet or for the FFVs. For the non-FFVs, cold-start THC emissions showed statistically significant differences between fuels, but not for the two FFVs. For the non-FFVs, cold-start THC emissions showed a marginally statistically significant increase of 16 percent (p=0.0539) for E15 compared to E10, while the alcohol mixture E10/Bu8 showed statistically significant reductions of 28 percent (p=0.0008), 23 percent (p=0.0218), 23 percent (p=0.0232), 27 percent (p=0.0026), and 25 percent (p=0.0087), respectively, compared to the E15, E20, Bu16, Bu24, and Bu32 blends over the combined FTP and UC cycles. For both the non-FFVs and FFVs, there were no statistically significant differences between fuels for the hot-running emissions of the FTP or UC cycle. For the hot-start THC emissions, the non-FFVs did not show any strong fuel effects for either of the test cycles. For the FFVs, the only statistically significant effect in hot-start THC emissions was a 38 percent (p=0.0064) reduction for Bu55 relative to E83.

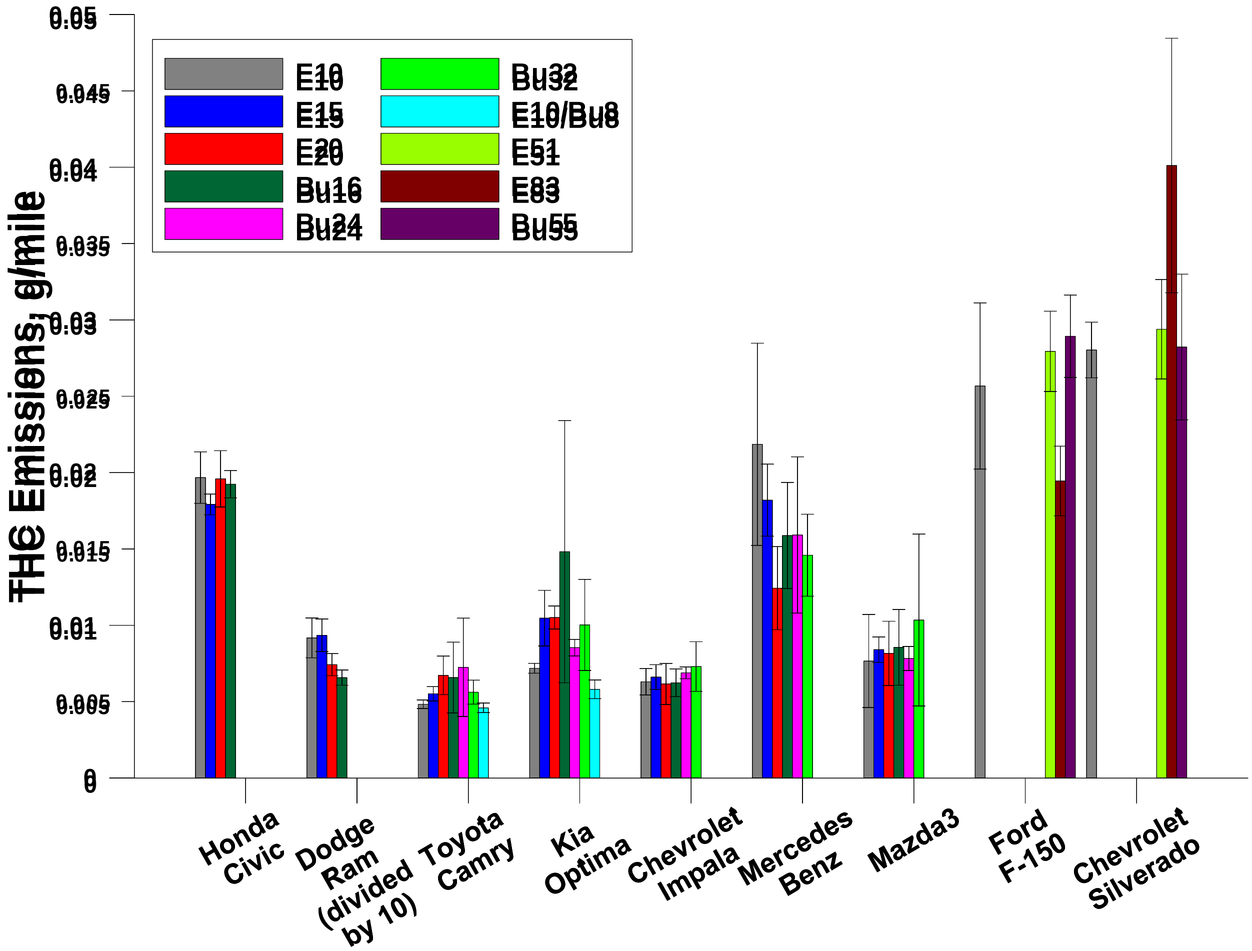
In comparison with previous studies, trends of decreasing THC emissions with increasing alcohol concentration have generally been seen for test cell engines or larger fleets of older technology vehicles (Knoll et al., 2009; Karavalakis et al., 2012; Schulz and Clark, 2011; Koc et al., 2009; Gu et al., 2012). This phenomenon has been widely attributed to the presence of oxygen content in the fuel, which leans the air-fuel ratio and promotes oxidation during combustion and over the catalyst. On the other hand, some increases in THC emissions with ethanol and butanol fuels have been observed in previous studies conducted with test cell engines and light-duty vehicles (Durbin et al., 2007; Dernotte et al., 2010). The lack of consistent fuel trends for THC emissions for the conventional vehicles and FFVs in the present study suggests THC emissions from modern vehicles with more sophisticated engine controls and catalysts are not as significantly impacted by the oxygen content of the fuel. For the SIDI vehicles, the increases in THC emissions were likely because of fuel impingement on combustion chamber surfaces. It is therefore reasonable to assume that a portion of THC emissions might be derived from unburned fuel during the initial stages of the cold-start portions of the FTP and UC.

Figure 8: THC Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

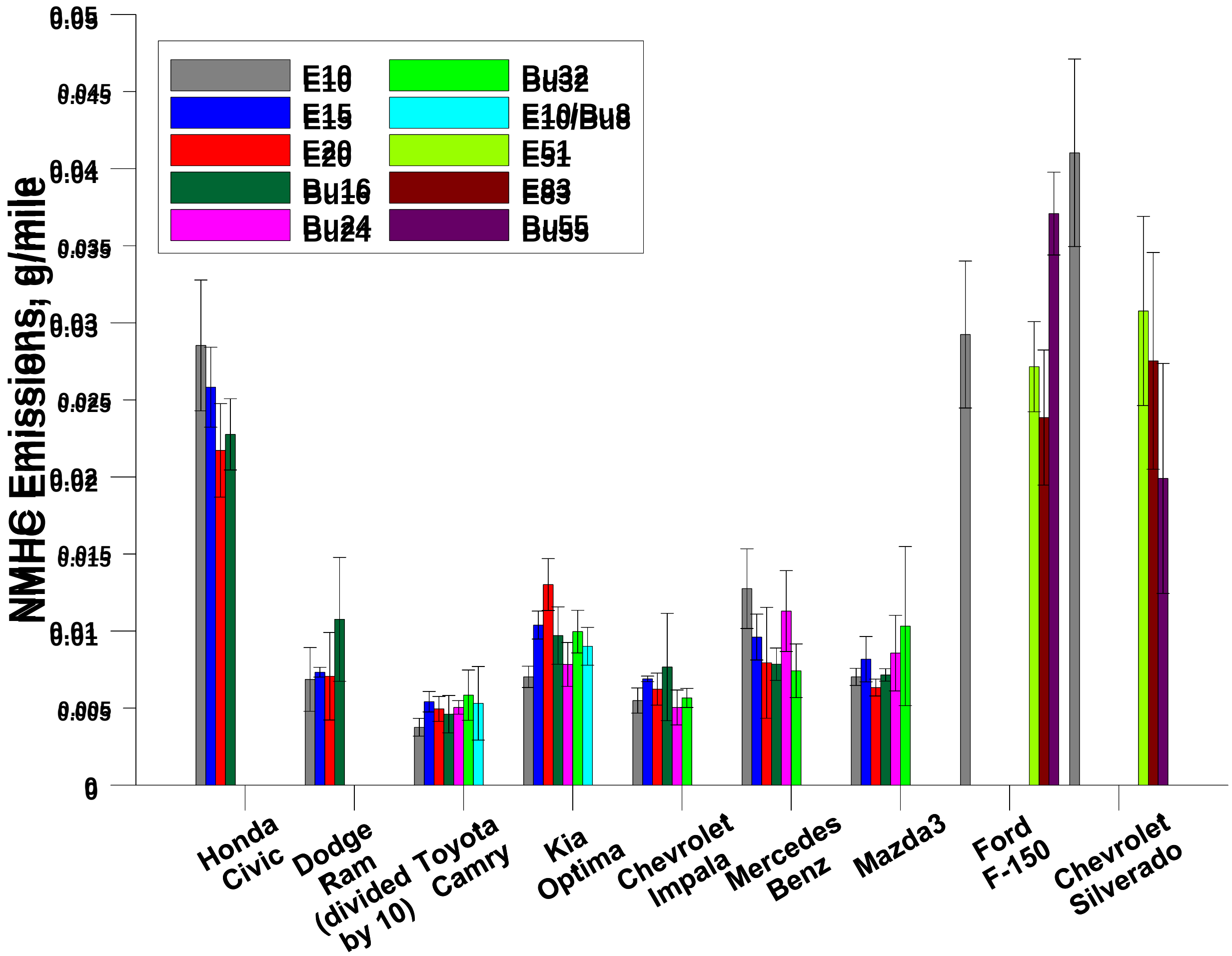
Figure 9: THC Emissions for All Vehicle/Fuel Combinations Over the UC Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

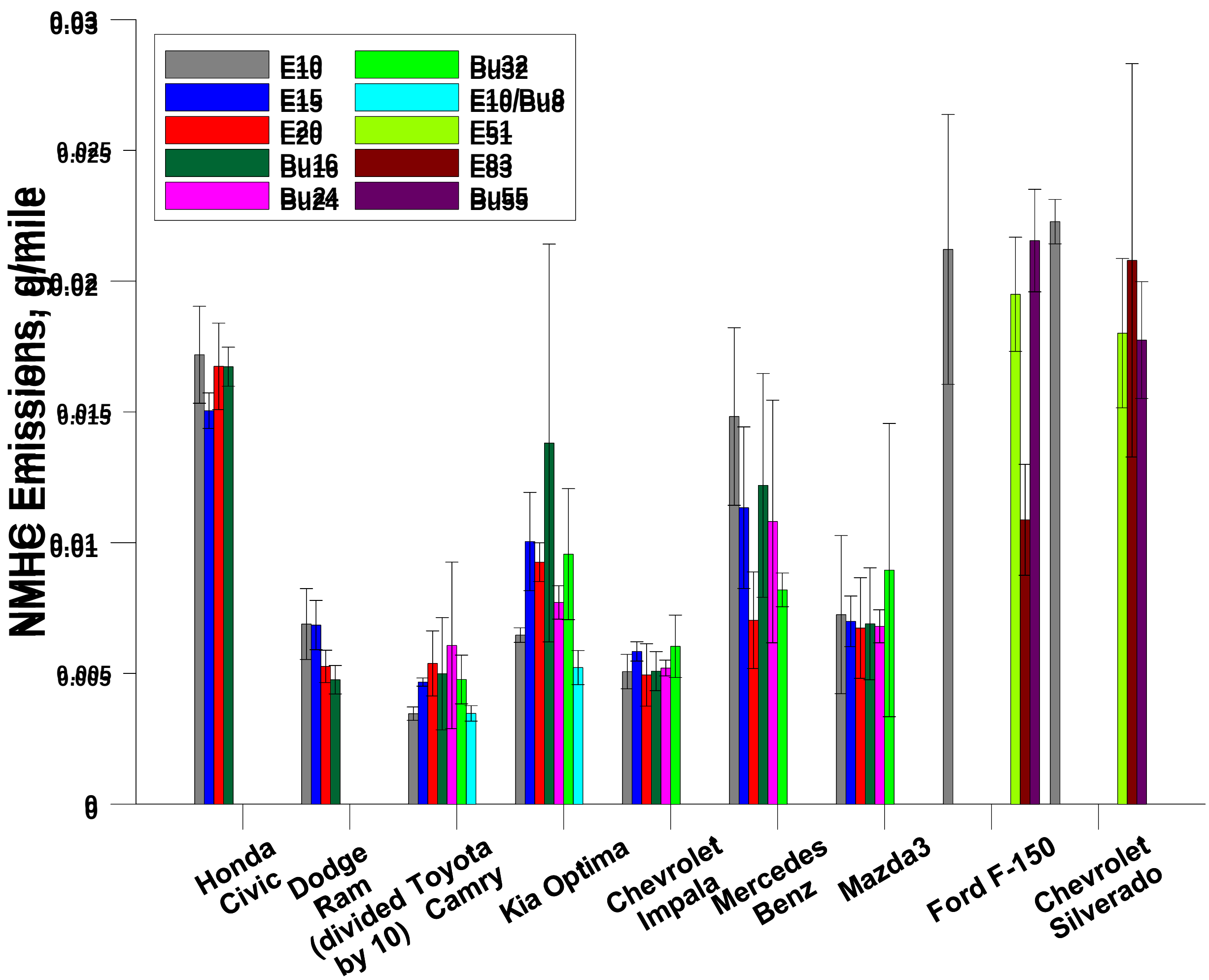
NMHC emissions are shown in Figure 10 and Figure 11. NMHC emissions followed similar patterns with THC emissions for most vehicles over both cycles. Analogous to THC emissions, the cold-start phase dominated the NMHC emissions, with the hot-running (bag 2) and hot-start (bag 3) NMHC emissions being at very low concentrations for most vehicles compared to bag 1 emission levels. Statistical analysis showed that for the conventional non-FFVs, the weighted NMHC emissions did not show any effects between the fuels, while for the FFVs the weighted NMHC emissions showed some statistically significant differences. For the FFVs, the weighted NMHC emissions showed a statistically significant decrease of 29 percent for E83 compared to the baseline E10 blend. For the cold-start phase, NMHC emissions did not show any fuel effect for the FFVs but showed strong differences between fuels for the conventional non-FFVs. Similar to cold-start THC emissions, cold-start NMHC emissions showed a marginally statistically significant increase of 17 percent (p=0.0503) for E15 relative to E10, while the mixture E10/Bu8 showed statistically significant decreases of 28 percent (p=0.0016), 22 percent (p=0.0438), 23 percent (p=0.0344), 27 percent (p=0.0053), and 24 percent (p=0.0238), compared to the E15, E20, Bu16, Bu24, and Bu32 blends. For both the non-FFVs and FFVs, were no consistent fuel effects for the hot-running and hot-start NMHC emissions for the FTP and UC cycle.

Figure 10: NMHC Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 11: NMHC Emissions for All Vehicle/Fuel Combinations Over the UC Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Although the emissions of CH_4 can contribute significantly to total CO_2-equivalent greenhouse gas (GHG) emissions, CH_4 emissions from mobile sources are not regulated in the U.S., as opposed to the EU. CH_4 is a more potent GHG compared to CO_2, with potency 21 times greater than CO_2 over 100 years, but CH_4 emissions are generally very low compared to CO_2 emissions. Emissions of CH_4 are a function of the type of fuel used, the design and tuning of the engine, the type of emission control system, the age of the vehicle, as well as other factors. As shown in Figure 12 and Figure 13, CH_4 emissions were found at very low levels ranged from 0.001 to 0.023 g/mile for the FTP and from 0.001 to 0.026 for the UC.

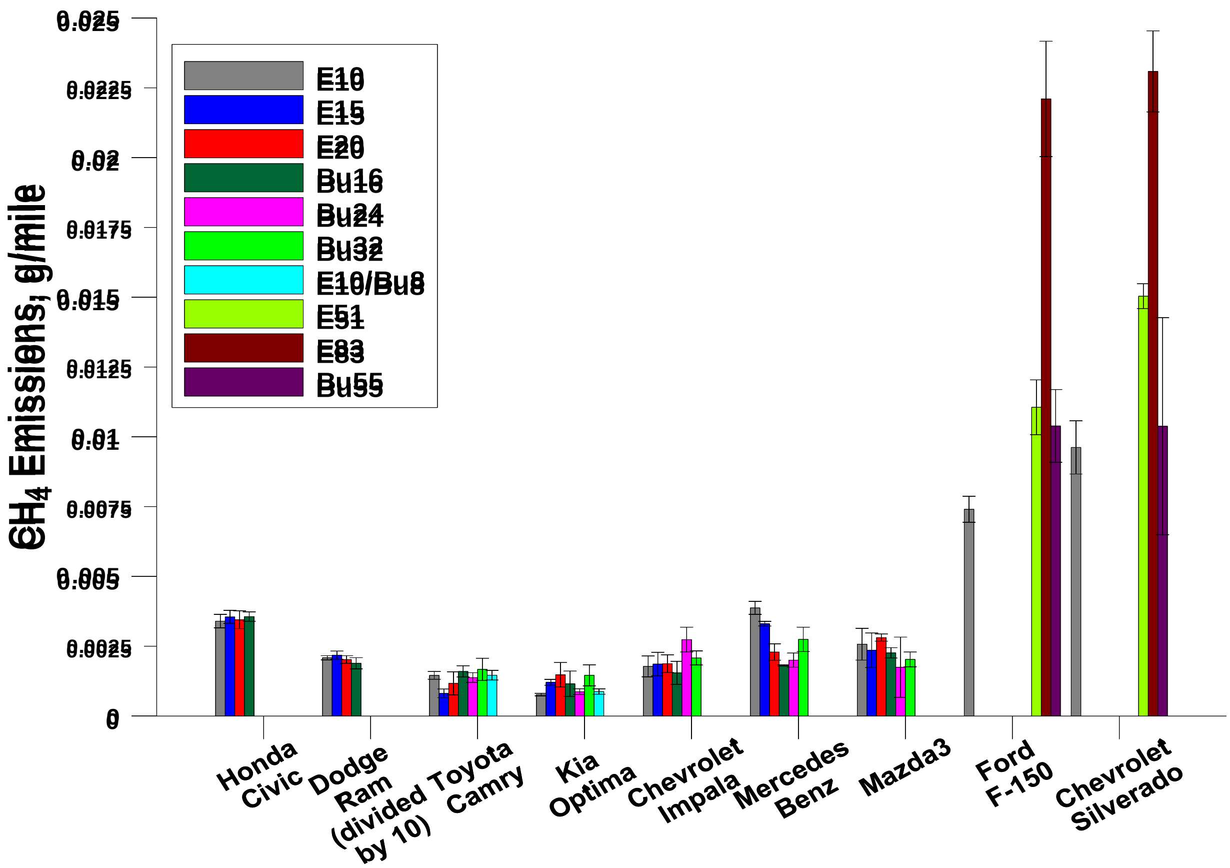
CH_4 emissions did not show any statistically significant differences between fuels for the weighted emissions of the FTP or UC cycle for the non-FFV vehicles. For the FFVs, however, weighted CH_4 emissions showed strong fuel differences for the FTP and UC cycles. For the FFVs, weighted CH_4 emissions showed statistically significant increases of 74 percent (p=<0.0001), 163 percent (p=<0.0001), and 43 percent (p=0.0002), respectively, for E51, E83, and

Bu55 compared to E10. A statistically significant increase in weighted CH_4 emissions of 51 percent (p=<0.0001) was also seen for E83 compared to E51, and a marginally statistically significant reduction of 17 percent (p=0.0806) for Bu55 compared to E51.

For the cold-start CH_4 emissions, the non-FFVs showed statistically significant reductions for the alcohol mixture E10/Bu8 of 27 percent (p=0.0074), 27 percent (p=0.0083), 27 percent (p=0.0117), and 31 percent (p=0.0011), respectively, compared to E15, E20, Bu24, and Bu32 blends, while a marginally statistically significant decrease of 22 percent (p=0.0860) was seen for the alcohol mixture compared to Bu16. For the FFVs, cold-start CH4 emissions showed statistically significant increases of 66 percent (p=<0.0001), 172 percent (p=<0.0001), and 40 percent (p=0.0029), respectively, for E51, E83, and Bu55 compared to E10. In addition, E83 showed a statistically significant increase of 64 percent (p=<0.0001) compared to E51 and Bu55 showed a statistically significant reduction of 49 percent (p=<0.0001) compared to E83. For the conventional non-FFVs, CH_4 emissions did not show any statistically significant differences between fuels for the hot-running and hot-start phases of the FTP or the UC cycles. For the FFVs, on the other hand, the fuel and driving cycle effects were particularly strong on the hot-running CH_4 emissions. For the hot-running FTP CH_4 emissions, E83 showed increases of 106 percent (p=0.0190) and 71 percent (p=0.0904), respectively, compared to E10 and E51 blends at statistically significant and marginally statistically significant levels, whereas Bu55 showed a statistically significant decrease of 57 percent (p=0.0072) relative to E83. For the hot-running UC CH_4 emissions, E51, E83, and Bu55 showed sharp increases of 268 percent (p=0.0031), 273 percent (p=0.0028), and 262 percent (p=0.0035), respectively, compared to the baseline E10, at a statistically significant level. For hot-start CH_4 emissions, fuels E51 and E83 showed statistically significant increases of 42 percent (p=0.0007) and 111 percent (p=<0.0001), respectively, compared to E10. For the hot-start CH_4 emissions, E83 showed an increase of 48 percent (p=0.0001), compared to E51, and Bu55 showed a decrease of 27 percent (p=0.0021) and 51 percent (p=<0.0001), respectively, compared to E51 and E83, all at a statistically significant level.

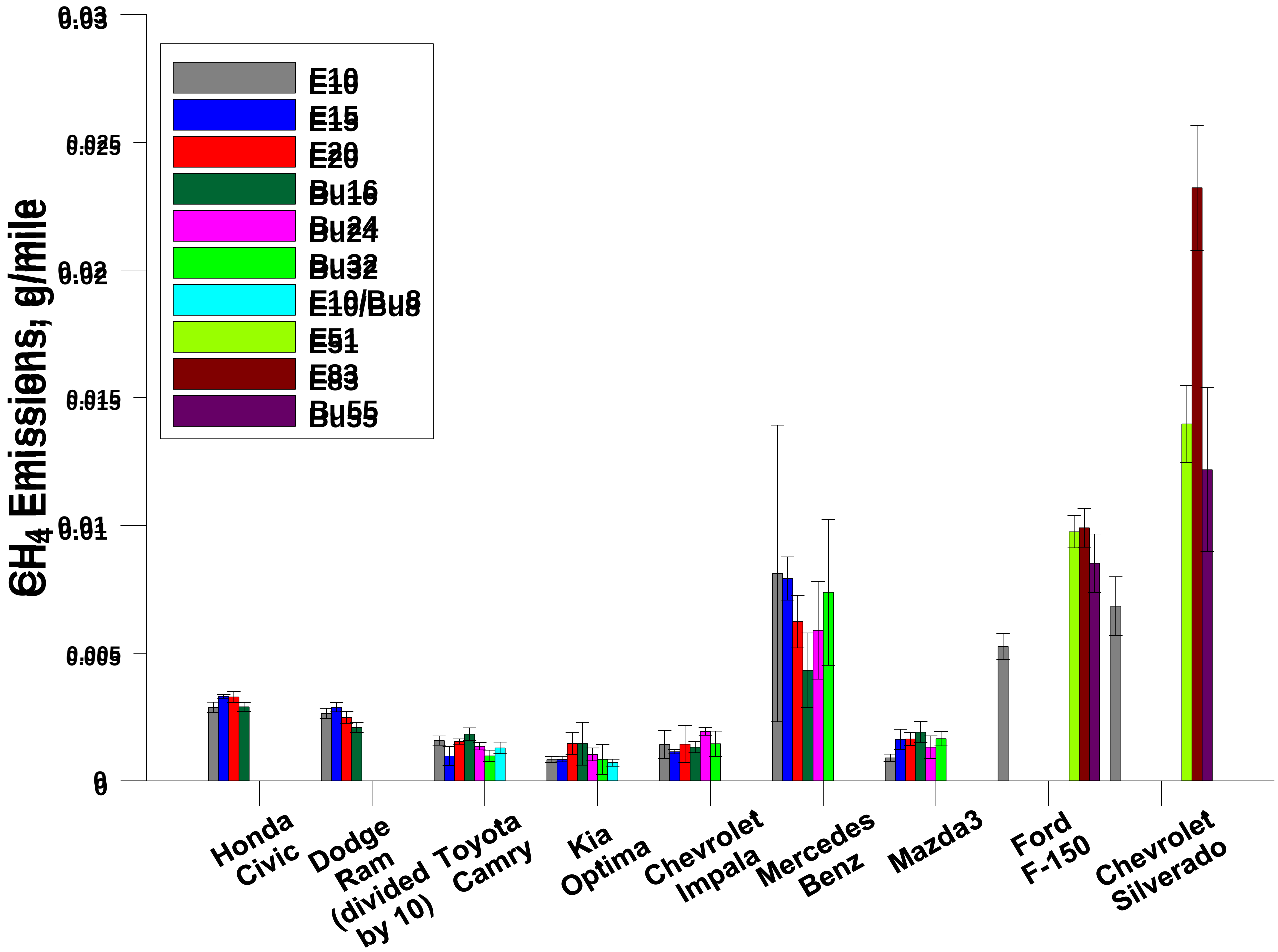
In general, it is expected that the use of alcohol fuels will decrease the emissions of CH_4 from SI combustion. The precursors of CH_4 formation are CH_3 and C_8H_{18}, which suggests that the addition of either ethanol or butanol to gasoline will inhibit the production of CH_4 via the C_8H_{18} decomposition pathway (Broustail et al., 2012). Under the present test conditions, our results did not reveal a global trend of lower CH_4 emissions with alcohol fuel formulations for the non-FFVs, but for the FFVs substantial increases in CH_4 emissions with E51, E83, and Bu55 compared to E10 were found. It should be noted that cold-start CH_4 emissions were found to be somewhat higher compared to hot-running and hot-start phases for both cycles, but the differences in emission levels were not as pronounced as observed with THC and NMHC emissions. This was probably due to the fact that CH_4 is more inert gas in terms of its oxidation activity in the TWC.

Figure 12: CH_4 Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 13: CH_4 Emissions for All Vehicle/Fuel Combinations Over the UC Cycle

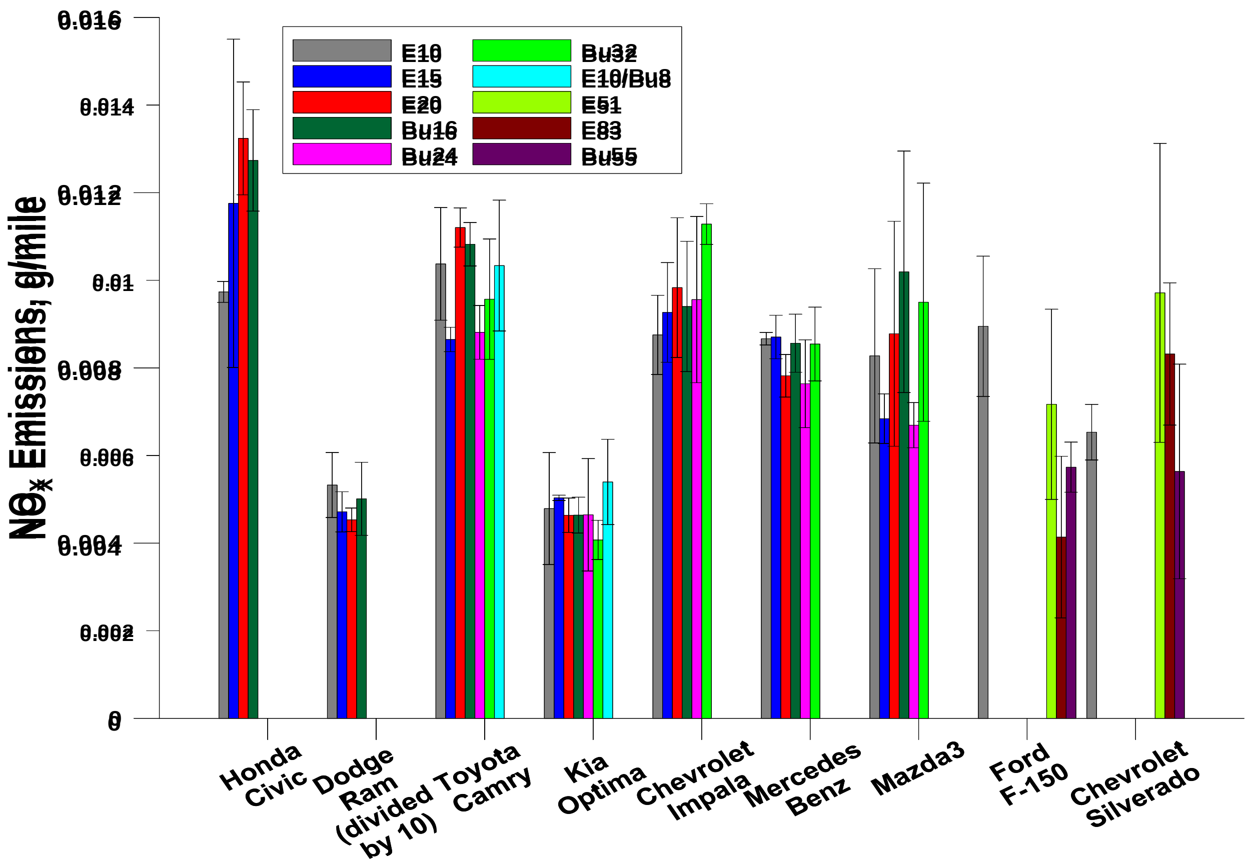


Errors bars represent ± one standard deviation around the average value for each fuel.

3.2 NO_x Emissions

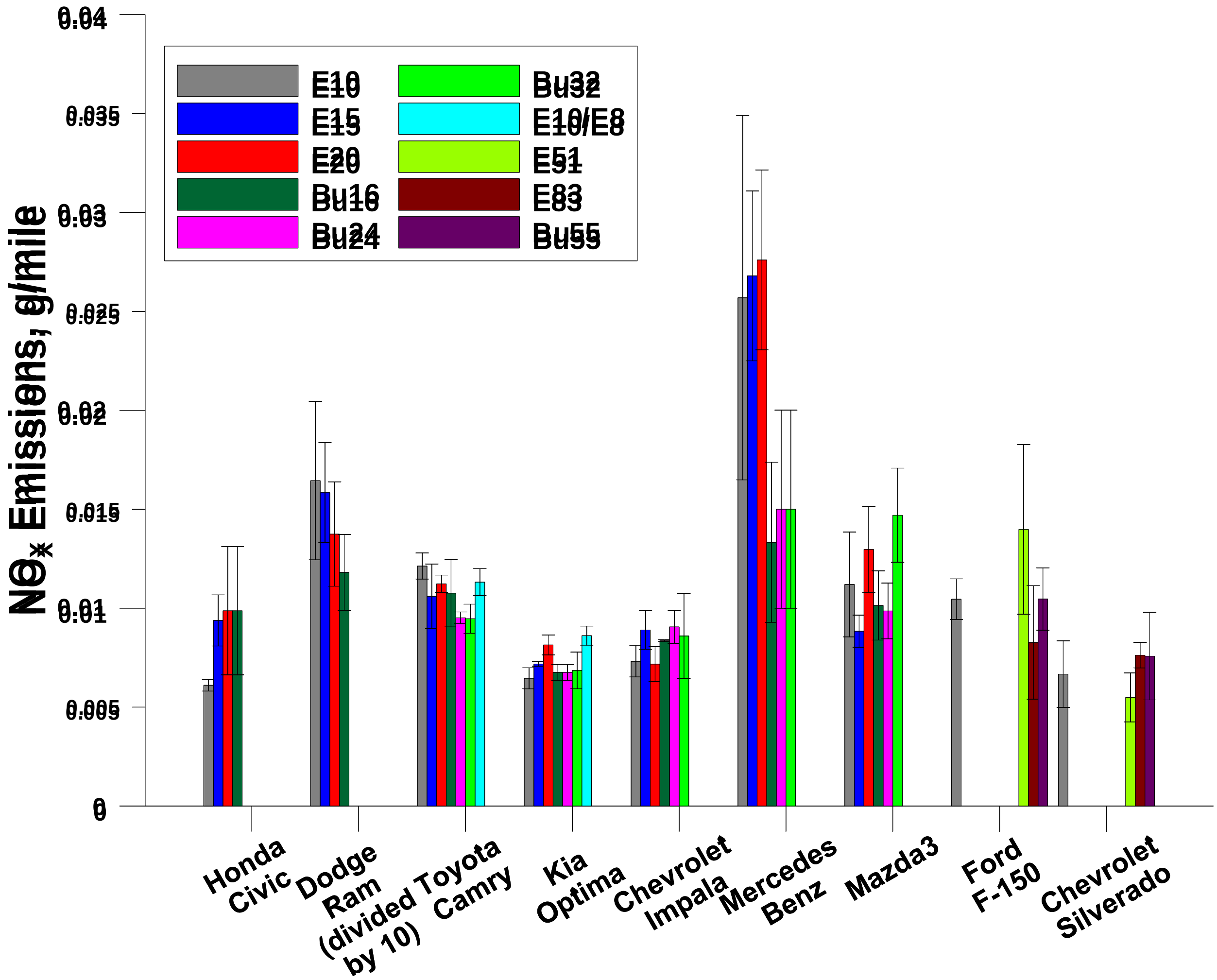
NO_x emissions as a function of fuel type are shown in Figure 14 for the FTP and in Figure 15 for the UC. The NO_x emissions for the Honda Civic, Toyota Camry, the SIDI vehicles, and the FFVs were about an order of magnitude lower than those for the Dodge Ram. For both the non-FFVs and FFVs, there were no statistically significant differences between fuels for the weighted emissions, of the FTP or UC cycle, and for the individual bag emissions only the NO_x emissions for bag 3 for the non-FFVs showed statistically significant or marginally statistically significant differences. For the hot-start NO_x emissions, for the non-FFVs, E20 and Bu16 blends showed statistically significant increases of 62percent (p=0.0080) and 52 percent (p=0.0341), respectively, compared to E10, while a marginally statistically significant increase of 53 percent (p=0.0754) for Bu32 was seen compared to E10.

Figure 14: NO_x Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 15: NO_x Emissions for All Vehicle/Fuel Combinations Over the UC Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

3.3 CO Emissions

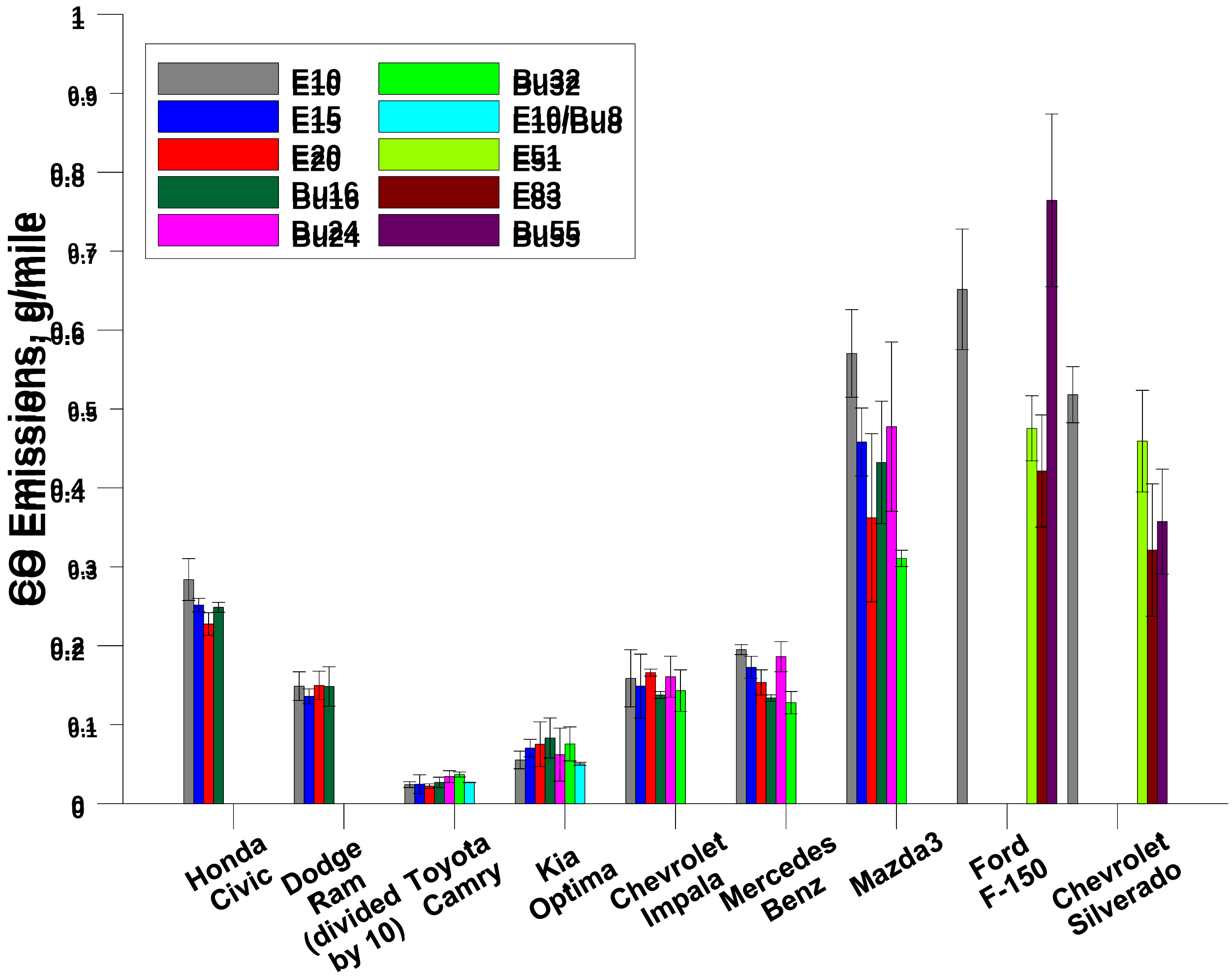
Figure 16 and Figure 17 present the influence of ethanol and iso-butanol addition on CO emissions for both cycles. CO emissions showed some strong fuel trends, with statistically significant or marginally statistically significant differences for the weighted emissions for both the non-FFVs and the FFVs. For the non-FFVs, weighted CO emissions showed a marginally statistically significant reduction of 23 percent (p=0.0836) for E10/Bu8 compared to E10 and a statistically significant reduction of 27 percent (p=0.0223) for E10/Bu8 compared to Bu24. For the FFVs, weighted CO emissions showed a statistically significant reduction of 43 percent (p=<0.0001) for E83 compared to E10, E83 showed a statistically significant decrease of 38 percent (p=<0.0001) compared to E51, and Bu55 showed a statistically significant increase of 63 percent (p=<0.0001) compared to E83.

CO emissions showed some of the strongest fuel trends at a statistically significant level during the cold-start phases of the FTP and UC cycles for both the non-FFVs and the FFVs. For the cold-start FTP CO emissions, for the non-FFVs, Bu32 showed statistically significant decreases of 24 percent (p=0.0077) and 21 percent (p=0.0291), respectively, compared to E10 and E15, while marginally statistically significant decreases of 19 percent (p=0.0724) and 21 percent (p=0.0961), respectively, were seen for Bu32 compared to Bu16 and Bu24. For the cold-start UC CO emissions, the alcohol mixture E10/Bu8 showed statistically significant reductions of 39 percent (p=0.0167), 43 percent (p=0.0038), 40 percent (p=0.0137), 43 percent (p=0.0032), and 43 percent (p=0.0045), respectively, compared to E15, E20, Bu16, Bu24, and Bu32 blends. For the FFVs, cold-start CO emissions showed statistically significant reductions of 40 percent (p=0.0011) and 36 percent (p=0.0064), respectively, for E83 compared to E10 and E51. The blend of Bu55 also showed a 59 percent (p=0.0036) increase in cold-start CO emissions compared to E83 at a statistically significant level.

For the non-FFVs, the hot-running and hot-start CO emissions did not show any strong fuel effects, as opposed to the FFVs. For the FFVs, for the hot-running FTP CO emissions, a marginally statistically significant increase of 135 percent (p=0.0560) was seen for Bu55 relative to E10. For the hot-running UC CO emissions, E83 showed statistically significant decreases of 55 percent (p=0.0006) and 58 percent (p=0.0002), respectively, compared to E10 and E51, and Bu55 showed an increase of 84 percent (p=0.0071) compared to E83, at a statistically significant level. For the hot-start CO emissions, E83 showed a statistically significant decrease of 57 percent (p=0.0136) relative to E10.

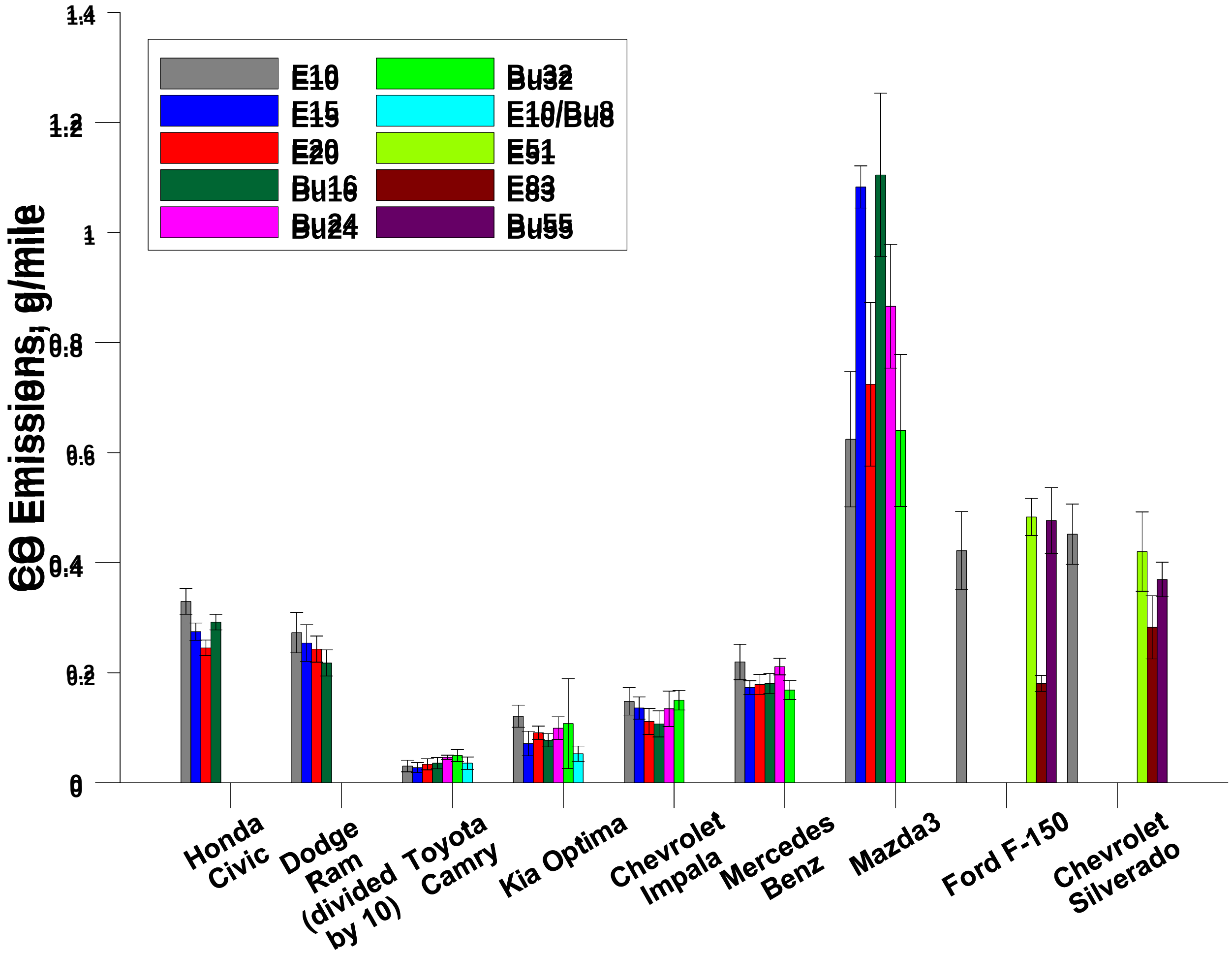
The general trend toward lower CO emissions with the higher alcohol fuel blends is consistent with previous studies that have shown reductions in CO with increasing alcohol content due to improved oxidation of the CO as a result of the oxygen content in the fuel (Knoll et al., 2009; Karavalakis et al., 2012; Schifter et al., 2011). For some vehicles, it was observed that the higher CO reductions were achieved with E20, E51, and E83 blends relative to E10. While it is hypothesized that the oxygen content was the primary contributing factor for the CO decrease, it might be possible that the CO decreases with the higher ethanol blends could be also a result of the considerably lower 50 percent distillation temperature (T50) compared to the other blends. This is in agreement with a previous study conducted by Durbin et al. (2007) where they found reduced CO emissions with lowering T50 in ethanol blends. This is also in agreement with the findings of the EPA study, which showed that both a combination of fuel-borne oxygen and lower T50 were responsible for lower CO emissions on a fleet of PFI vehicles when running on ethanol blends (US EPA, 2013). It should be emphasized that similar to THC/NMHC emissions, CO emissions were dominated by the cold-start portion of the FTP and UC test cycles. The significantly higher CO emissions during cold-start compared to hot-running and hot-start emissions suggest that the combustion was rich during the first 200-300 seconds of the test cycles in addition to the catalyst being below its light-off temperature.

Figure 16: CO Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 17: CO Emissions for All Vehicle/Fuel Combinations Over the UC Cycle



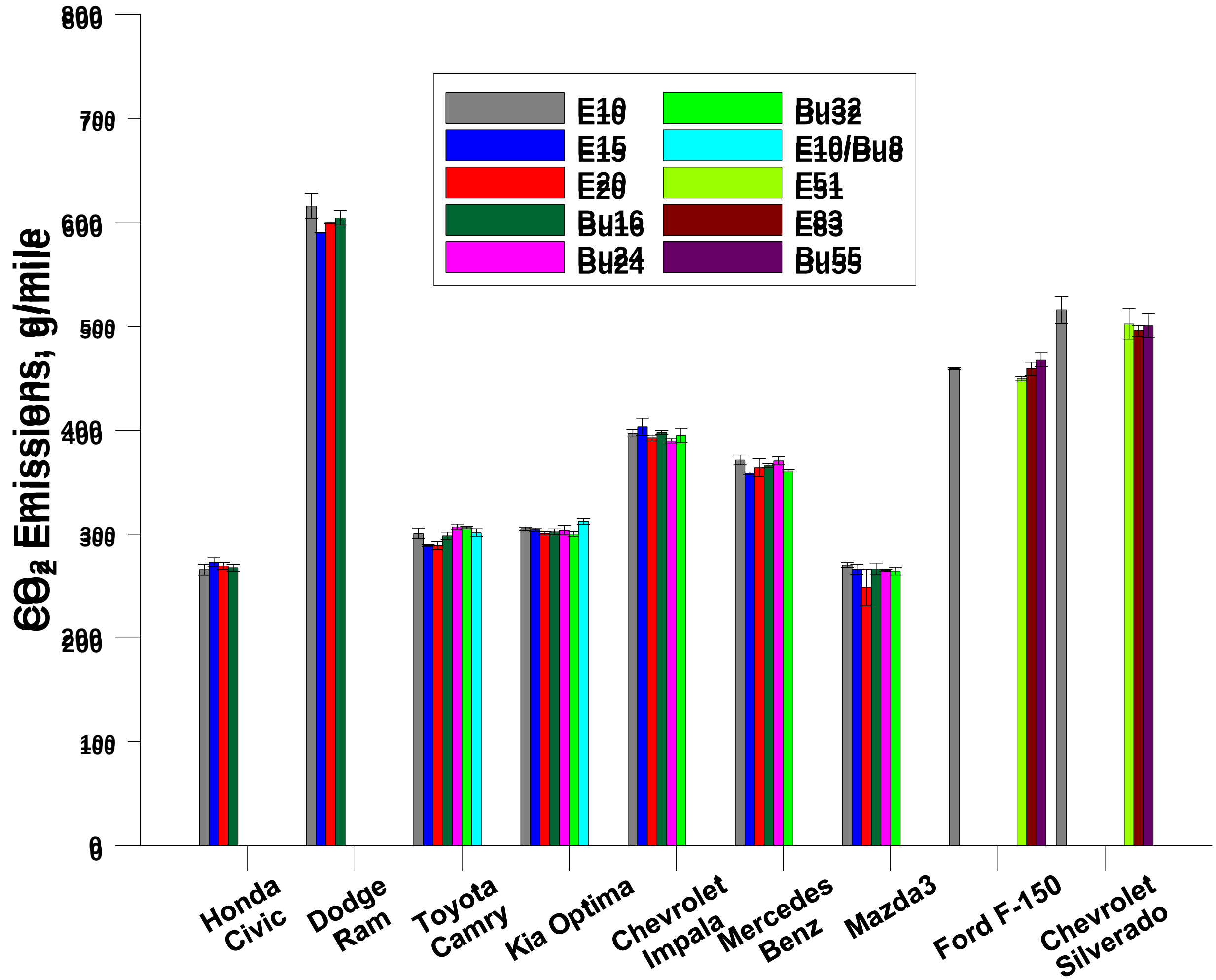
Errors bars represent ± one standard deviation around the average value for each fuel.

3.4 CO_2 Emissions and Fuel Economy

Figure 18 and Figure 19 show the effect of alcohol type and concentration on the CO_2 emissions for the test vehicles over the FTP and UC, respectively. Weighted CO_2 emissions did show some statistically significant differences for both the non-FFVs and FFVs. For the non-FFVs, weighted CO_2 emissions showed a statistically significant decrease of 3 percent (p=0.0009) for E20 relative to E10, whereas Bu24 and E10/Bu8 showed statistically significant increases of 3 percent (p=0.0106) and 3 percent (p=0.0154), respectively, and a marginally statistically significant increase of 2 percent (p=0.0906) compared to E20. For the FFVs, weighted CO_2 emissions did not show any strong trends between fuels for the FTP cycle, whereas for the UC some statistically significant and marginally significant differences for the fuels tested were observed. For the FFVs, E83 showed statistically significant decreases in weighted CO_2 emissions of 4 percent (p=0.0490) and 6 percent (p=0.0107), respectively, compared to E10 and E51, while Bu55 showed a marginally statistically significant increase of 4 percent (p=0.0655) compared to E83. From a theoretical standpoint, it might be expected that CO_2 emissions would trend with the carbon/hydrogen ratio in the fuel, with higher CO_2 emissions for fuels with higher carbon/hydrogen ratios. This is consistent with the results that showed some reductions for the higher alcohol blends, which have lower carbon/hydrogen ratios, but it was not consistent for the different segments or bags of the test cycles, or for many of the different vehicle/cycle combinations.

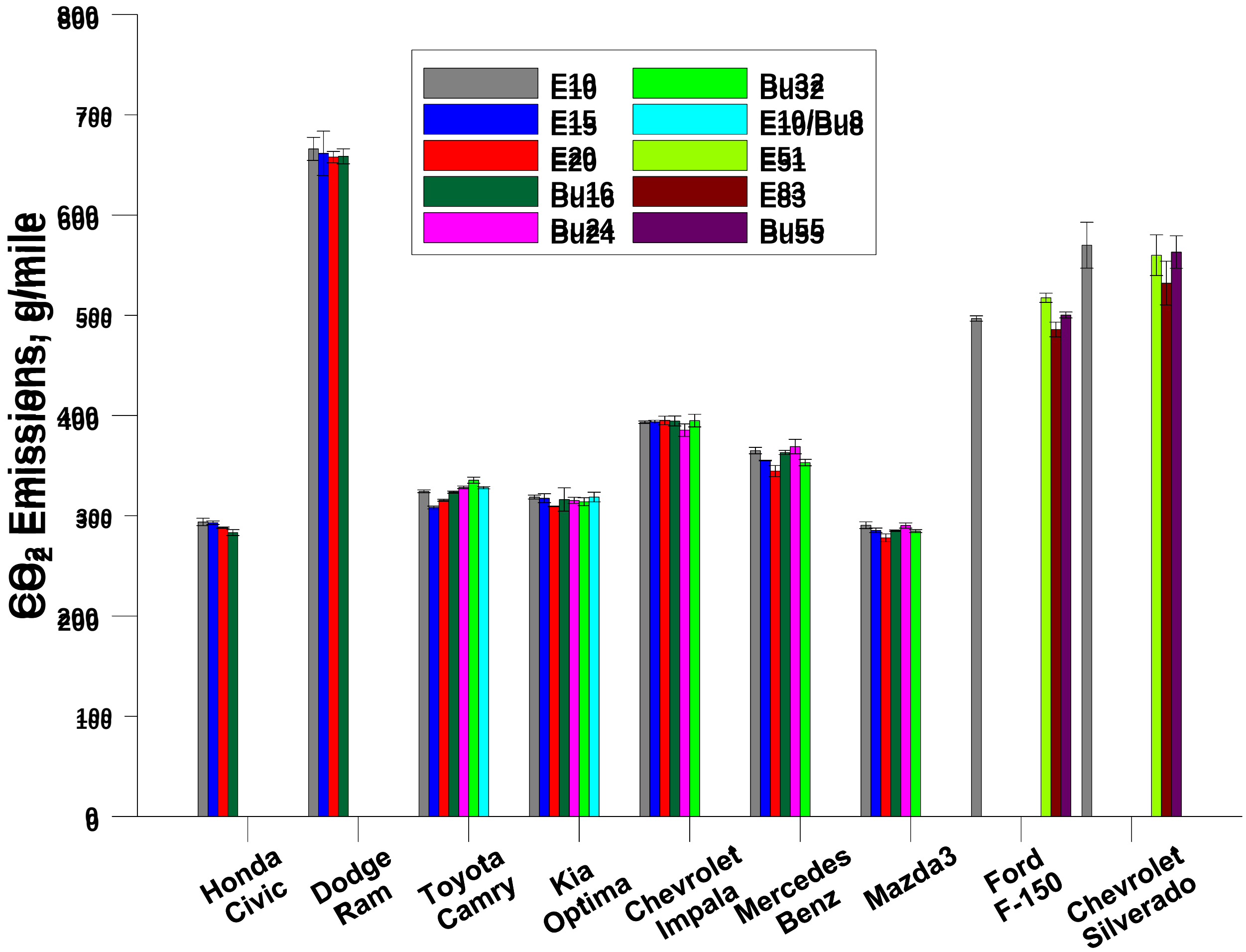
For the non-FFVs, for the cold-start CO_2 emissions, E20 showed a statistically significant reduction of 2 percent (p=0.0271) relative to E10, while the butanol blends of Bu16, Bu24, and Bu32 showed statistically significant increases in CO_2 emissions of 2 percent (p=0.0453), 5 percent (p=<0.0001), and 4 percent (p=0.0006), respectively, compared to E20. For the FFVs, for the cold-start CO_2 emissions, E83 showed a statistically significant decrease of 3 percent (p=0.0489) relative to E10, and Bu55 showed a statistically significant increase of 3 percent (p=0.0438) relative to E83. For the hot-running CO_2 emissions, for the non-FFVs, the only significant difference was observed between E10 and E20 blends, with E20 showing a 2 percent (p=0.0598) reduction in CO_2 emissions compared to E10 at a marginally statistically significant level. For the FFVs, E83 showed statistically significant reductions in CO_2 emissions of 4 percent (p=0.0162) and 6 percent (p=0.0007), respectively, compared to E10 and E51, while Bu55 showed a statistically significant increase of 4 percent (p=0.0374) compared to E83. For the hot-start CO_2 emissions, the FFVs did not show any statistically significant effect between fuels for the FTP or UC cycles, while the non-FFVs showed some statistically significant differences between some fuels. For the non-FFVs, hot-start CO_2 emissions for E20 showed a statistically significant reduction of 2 percent (p=0.0193) relative to E10 and Bu24 showed a statistically significant increase of 2 percent (p=0.0147) relative to E20.

Figure 18: CO_2 Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 19: CO_2 Emissions for All Vehicle/Fuel Combinations Over the UC Cycle



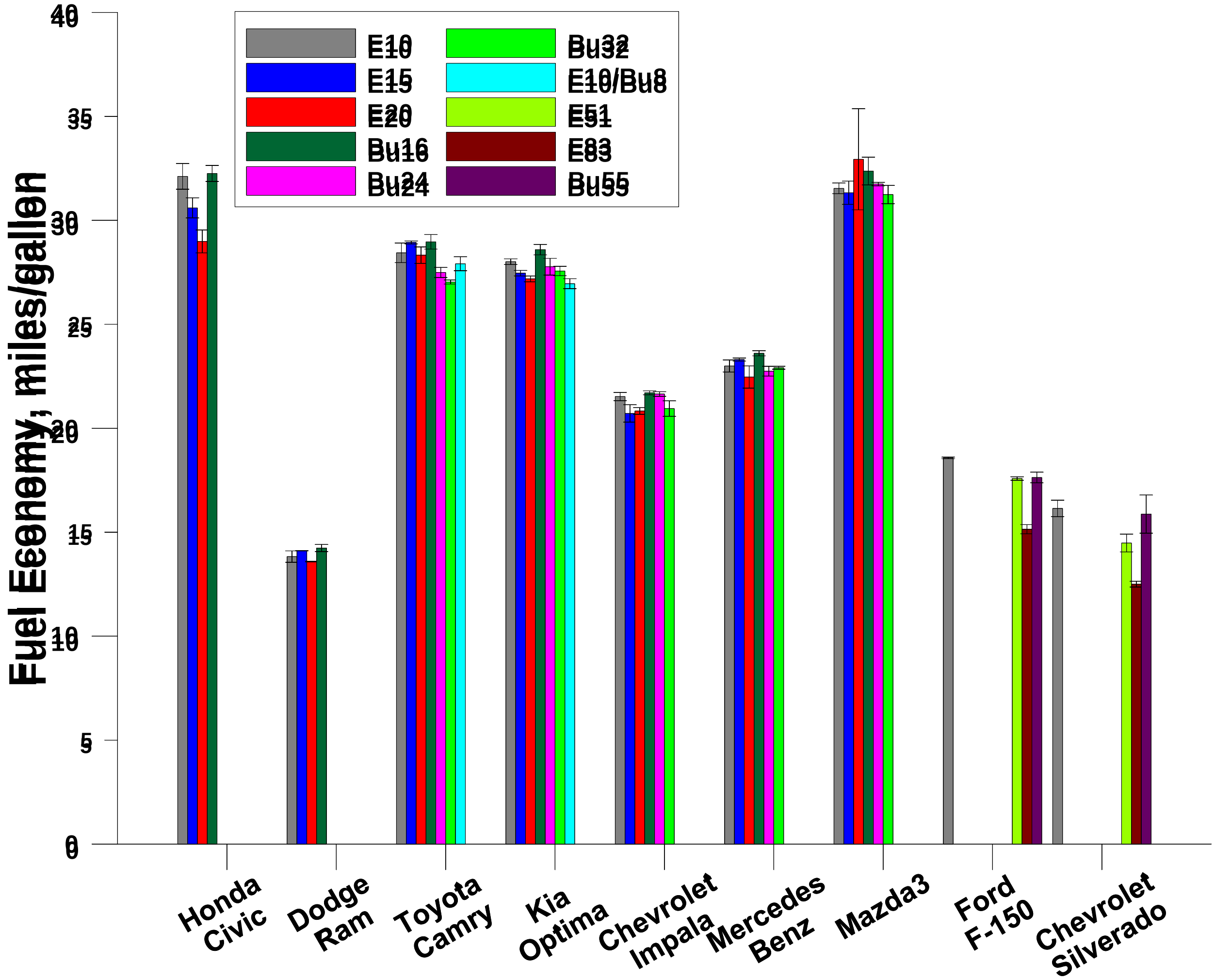
Errors bars represent ± one standard deviation around the average value for each fuel.

Fuel economy for each vehicle/fuel combination is presented in Figure 20 and Figure 21for the FTP and UC test cycles, respectively. Fuel economy was calculated based on the carbon balance method and the unique properties for each different test fuel and not according to the standard EPA equation. The carbon balance equation more directly accounts for the differences in energy content between different fuels, which are somewhat normalized out in the standard EPA equation. The fuel economy showed trends consistent with the energy differences in the fuels. In comparison with the E10 fuel, the E15, E20, Bu16, B24, Bu32, E51, E83, and Bu55 fuels had energy contents that were lower by 3 percent, 5.7 percent, 2.3 percent, 2.3 percent, 17 percent, 36 percent, and 9.7 percent.

Both the non-FFVs and the FFVs showed statistically significant fuel differences for fuel economy. For the weighted fuel economy, the FFVs showed the strongest fuel trends when compared to the conventional non-FFVs. For the non-FFVs, statistically significant decreases in weighted fuel economy of 2 percent (p=0.0455) were found for E20 compared to E10, and of 3 percent (p=0.0041), 4 percent (p=<0.0001), and 4 percent (p=0.0075), respectively, for Bu24, Bu32, and E10/Bu8 compared to Bu16. The blend of Bu32 also showed a decrease in weighted fuel economy of 2 percent (p=0.0544) relative to E10, but at a marginally statistically significant level. The blend of Bu16 showed statistically significant increases in weighted fuel economy of 3 percent (p=0.0031) and 4 percent (p=<0.0001), respectively, compared to E15 and E20, and a marginally statistically significant increase of 2 percent (p=0.0945) compared to E10. For the FFVs, weighted fuel economy showed statistically significant reductions of 13 percent (p=<0.0001), 24 percent (p=<0.0001), and 7 percent (p=<0.0001), respectively, for E51, E83, and Bu55 compared to E10. The blend of E83 also showed a statistically significant reduction in weighted fuel economy of 12 percent (p=<0.0001) relative to E51, while Bu55 was statistically significant higher of 7 percent (p=<0.0001) and 22 percent (p=<0.0001) compared to E51 and E83, respectively.

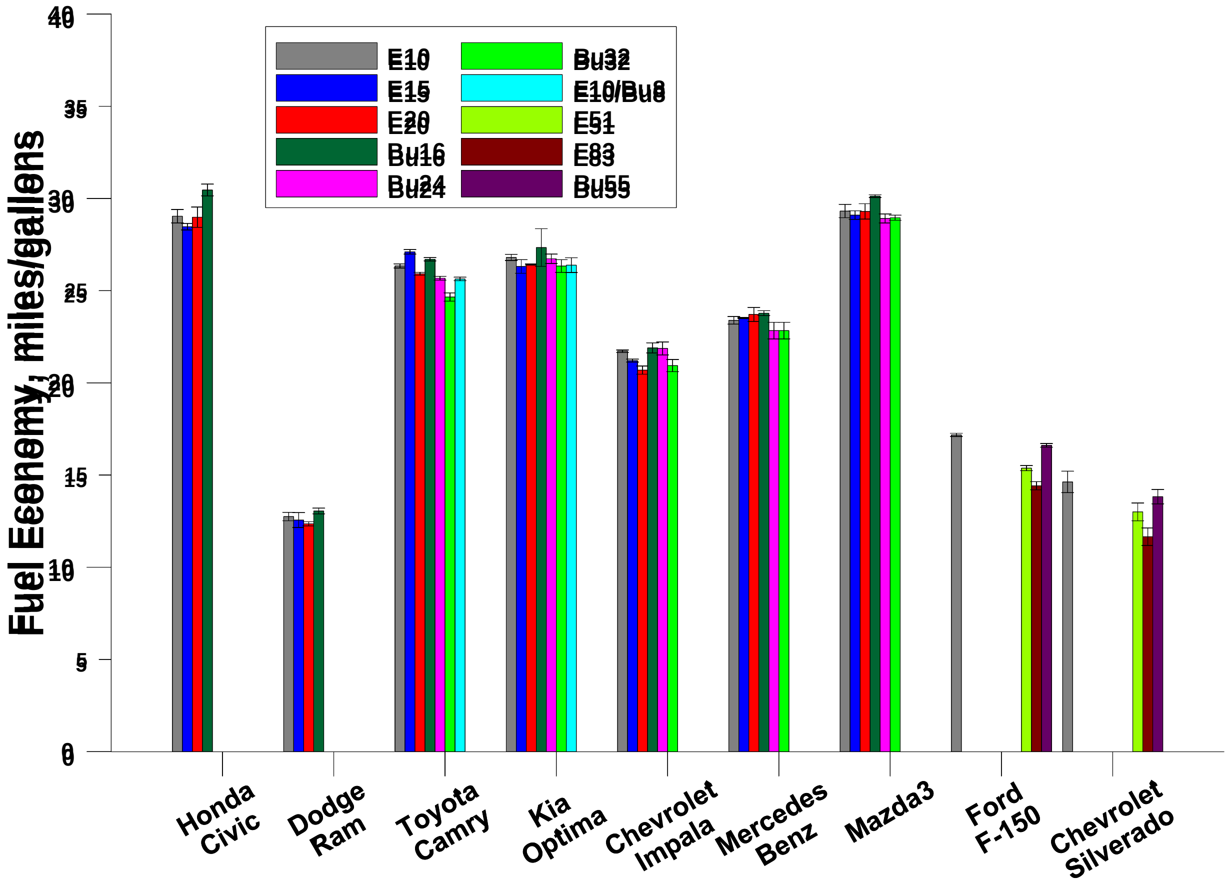
For the cold-start fuel economy, there were no significant fuel effects for the conventional non-FFVs, while for the FFVs some strong fuel trends were observed for both the FTP and UC cycles. For the cold-start fuel economy, for the FTP, fuels E51, E83, and Bu55 showed statistically significant reductions of 16 percent (p=<0.0001), 29 percent (p=<0.0001), and 11 percent (p=<0.0001), respectively, compared to E10, while E83 showed a statistically significant reduction of 16 percent (p=<0.0001) compared to E51. Similar to weighted fuel economy, Bu55 showed statistically significant increases of 5 percent (p=0.0401) and 25 percent (p=<0.0001), respectively, compared to E51 and E83 blends. For the UC, fuel economy showed statistically significant reductions of 33 percent (p=<0.0001), 40 percent (p=<0.0001), and 28 percent (p=0.0003), respectively, for E51, E83, and Bu55 compared to E10, while Bu55 showed a statistically significant increase of 19 percent (p=0.0129) compared to E83. For the hot-running phase, for the non-FFVs, fuel economy showed a marginally statistically significant increase of 3 percent (p=0.0924) and a statistically significant increase of 4 percent (p=0.0012) for Bu16 compared to E15 and E20, respectively. Fuel economy for Bu32 and E10/Bu8 showed a statistically significant decrease of 4 percent (p=0.0038) and a marginally statistically significant decrease of 4 percent (p=0.0692), respectively, compared to Bu16. For the FFVs, hot-running fuel economy for E51, E83, and Bu55 showed statistically significant decreases of 13 percent (p=<0.0001), 24 percent (p=<0.0001), and 7 percent (p=0.0003), respectively, compared to E10, while E83 showed a statistically significant decrease of 12 percent (p=<0.0001) compared to E51. The Bu55 blend showed statistically significant increases in fuel economy of 8 percent (p=<0.0001) and 23 percent (p=<0.0001), respectively, compared to E51 and E83. For the hot-start phase, the non-FFVs did not show any strong trends in fuel economy between the fuel blends for the FTP or UC cycles. For the FFVs, hot-start fuel economy for E51 and E83 showed statistically significant decreases of 15 percent (p=0.0315) and 26 percent (p=<0.0001), respectively, compared to E10, while E83 showed a statistically significant decrease of 13 percent (p=0.0325) compared to E51. The butanol blend showed a statistically significant increase in fuel economy of 18 percent (p=0.0065) compared to E83.

Figure 20: Fuel Economy for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 21: Fuel Economy for All Vehicle/Fuel Combinations Over the UC Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

3.5 PM Mass, Particle Number, and Black Carbon Emissions

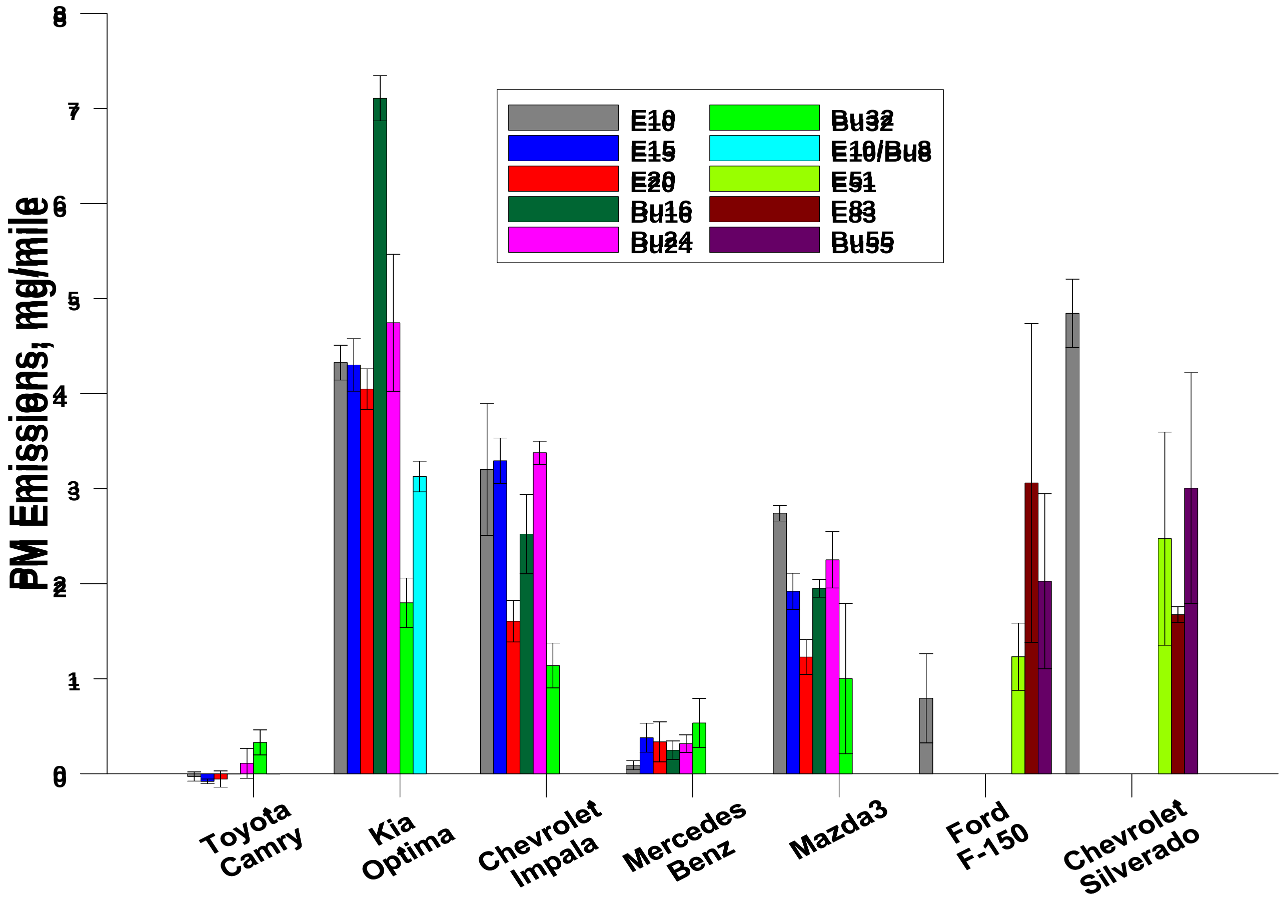
The cumulative PM mass emissions are shown in Figures 21 and 22 for the FTP and UC cycles, respectively. PM mass was only collected for the Toyota Camry, the SIDI vehicles, and the FFVs. It should be noted that for the Toyota Camry, PM mass emissions were found to be below the tunnel background levels for most fuel blends for the FTP. Overall, PM emission results showed reductions with higher oxygen levels for a number of the vehicle/cycle combinations. Other properties, such as fuel volatility, can also play a role in PM emissions, which is sometimes more important than the presence of oxygen in the fuel. However, in the current study most physicochemical properties of the test fuels were kept constant with relatively narrow ranges. Thus, the oxygen content should be the primary contributing factor for lowering PM mass emissions.

PM mass emissions showed some strong differences between fuels for both the conventional non-FFVs and the FFVs. For the non-FFVs, PM mass emissions Bu16 and Bu24 showed increases of 81 percent (p=0.0901) and 94 percent (p=0.0176), respectively, compared to E20 at marginally statistically significant and statistically significant levels. For the FFVs, PM mass emissions did not show any fuel effect over the FTP cycle, but showed some significant differences during UC operation. For the UC, PM mass emissions for E51, E83, and Bu55 showed statistically significant decreases of 61 percent (p=0.0083), 59 percent (p=0.0114), and 52 percent (p=0.0114), respectively, compared to E10.

While this study employed relatively modern vehicles, it appears that additional reductions in PM emissions will be needed to meet the future California LEV III and Tier 3 standards for PM mass emissions to be implemented by 2021 (3 mg/mile), and in particular the even more stringent LEV III PM mass standards for 2025 (1 mg/mile). PM mass results ranged from 0.09 to 7.11 mg/mile for the FTP and 0.08 to 6.64 for the UC, averaging 0.06 and 0.36 mg/mile for the Toyota Camry, 4.21 and 4.75 mg/mile for the Kia Optima, 2.52 and 2.56 mg/mile for the Chevrolet Impala, 0.32 and 0.31 mg/mile for the Mercedes Benz, 1.85 and 1.57 mg/mile for the Mazda3, 1.78 and 1.03 mg/mile for the Ford F-150, and at 3.00 and 2.45 mg/mile for the Chevrolet Silverado for the FTP and UC, respectively. This study showed considerably higher PM mass emissions from the wall-guided SIDI vehicles compared to the PFI vehicles and the spray-guided SIDI vehicle. This study also revealed that a high displacement light-duty truck equipped with a PFI engine, however, may also emit about the same PM mass emissions as a gasoline passenger car equipped with wall-guided DI engine.

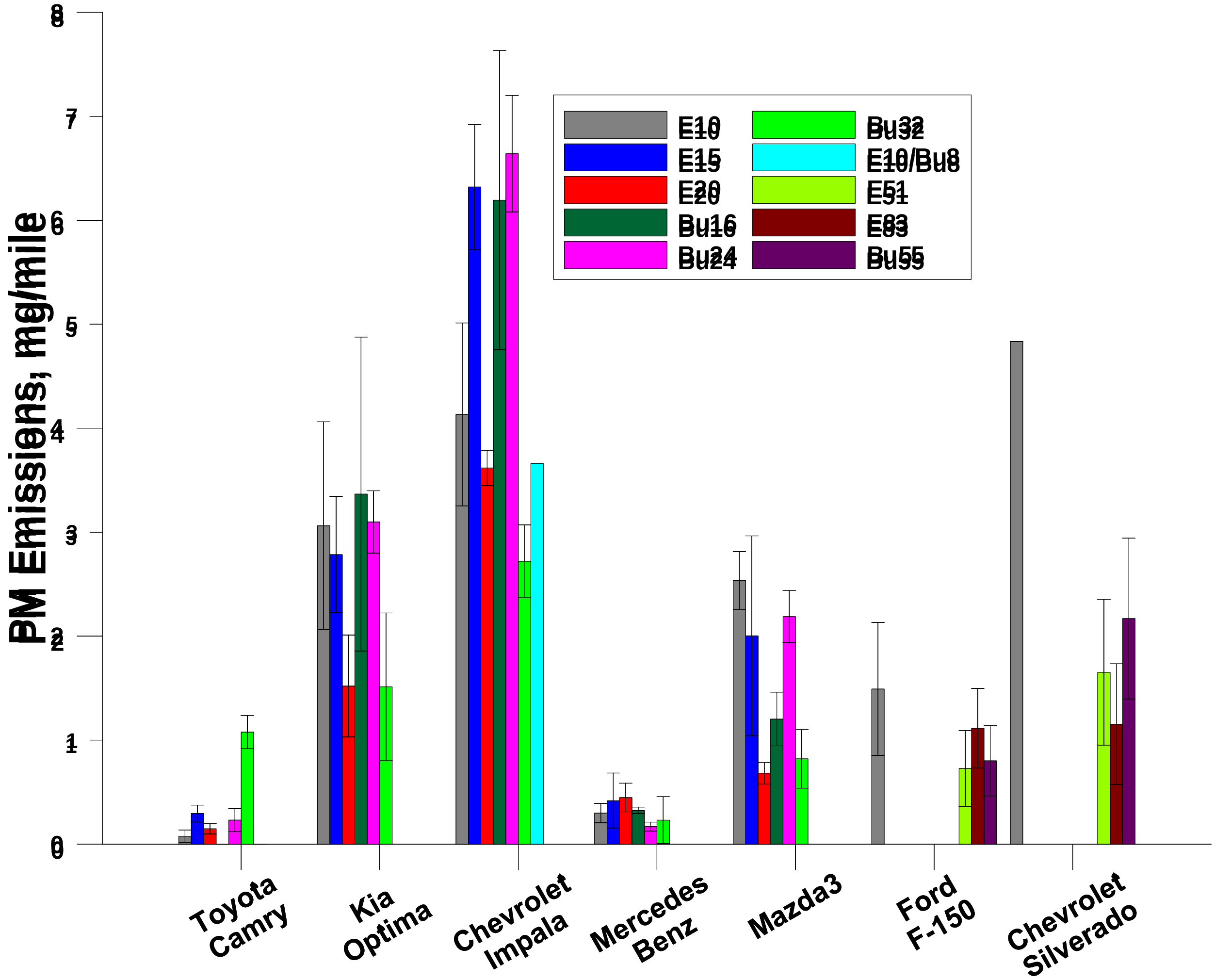
Higher PM emissions for the SIDI fueled vehicles are expected and have been reported in previous studies (Storey et al., 2012; Maricq et al., 2013; Li et al., 2014). Our results are also in agreement with a more recent study of PFI vehicles of model year 2005 and newer, which show PM mass rates of < 1 mg/mile over the FTP (Zhang et al., 2012). Elevated PM mass emissions from SIDI vehicles can be ascribed to insufficient homogeneous mixture and subsequent fuel evaporation, wall wetting, and a less efficient mixing of air and fuel compared to PFI vehicles, where the fuel is injected and vaporized into the intake ports (Piock et al., 2011). In addition, the higher PM emissions from the SIDI vehicles were predominantly released from the cold-start phase where cold piston and cylinder surfaces exacerbate liquid fuel impingement and reduce evaporation from surfaces, which produces soot when the fuel ignites (Maricq et al., 2013). The substantially lower PM mass emissions for the spray-guided vehicle as compared to the wall-guided vehicles could be ascribed to the higher injection pressure, relatively better mixture preparation, and reduced impingement of fuel on the combustion chamber surfaces (Piock et al., 2011).

Figure 22: PM Mass Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 23: PM Mass Emissions for All Vehicle/Fuel Combinations Over the UC Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

The total particle number emissions are displayed in Figure 24and Figure 25 for the FTP and UC cycles, respectively. For most vehicles, particle number emissions corroborate the PM mass trends, with the exception of the PFI Ford F-150. In general, the SIDI vehicles exhibited significantly higher particle number counts compared to their PFI counterparts, noting that the PN emissions for the PFI vehicles are multiplied by a factor in the graphs. It is interesting to note that the PFI Ford F-150 FFV produced similar particle number counts to the spray-guided Mercedes Benz. The lower particle number emissions for PFI vehicles can be attributed to the better mixture preparation of PFI engines in relation to SIDI engines and the likelihood of fuel impingement onto the piston for the SIDI engines. This may result in liquid fuel that is totally vaporized at the start of combustion. As a consequence, local fuel-rich combustion or even pool fires can occur near the piston, generating high particle emissions (Piock et al., 2011; Whelan et al., 2010; He et al., 2010). Overall, the more aggressive driving conditions for the UC increased particle number counts for all vehicle/fuel combinations compared to the FTP. As previously discussed, the main contributing factors for the lower particle number emissions for the spray-guided SIDI vehicle as compared to the wall-guided SIDI vehicles could be the reduced time for mixture preparation and less fuel wetting.

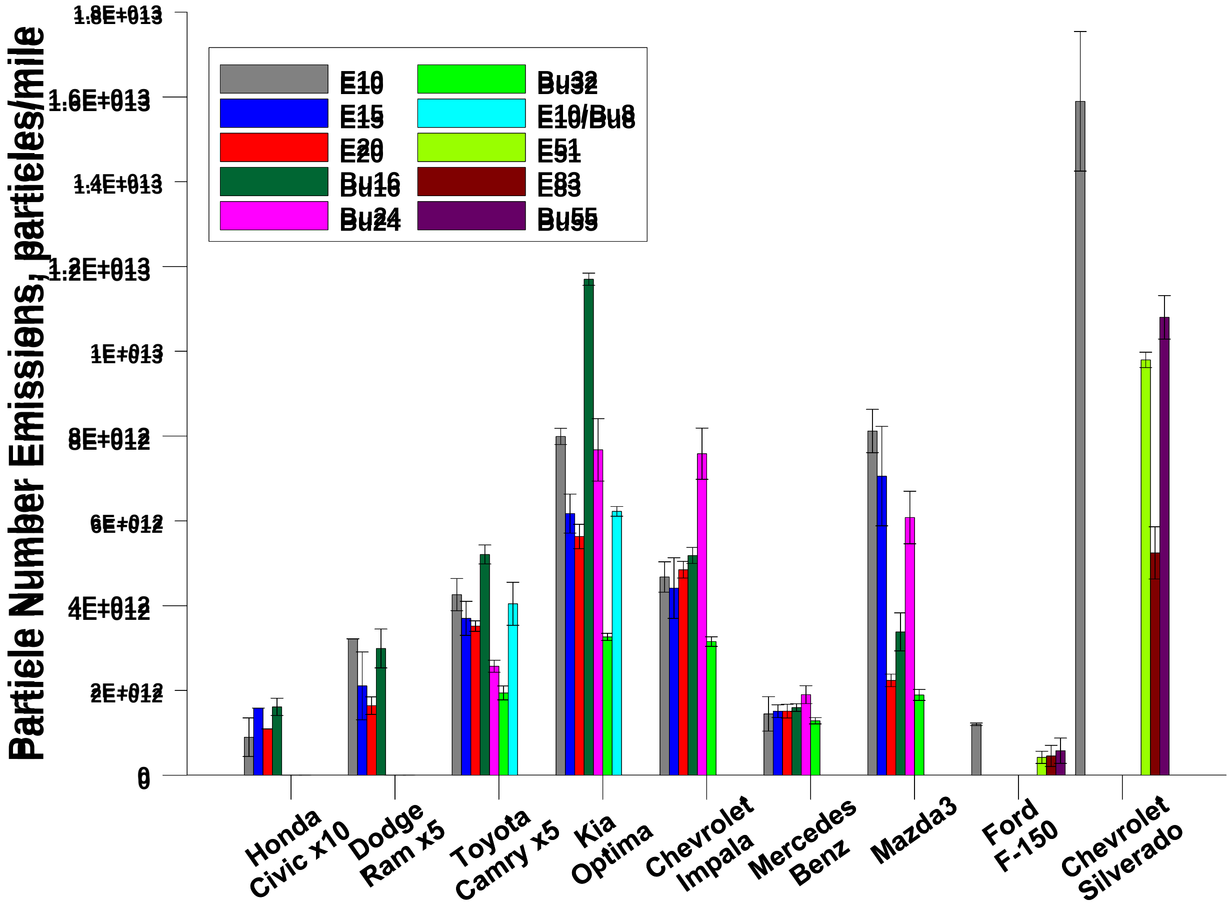
Weighted particle number emissions showed fuel impacts for both the non-FFVs and the FFVs. For the non-FFVs, particle number emissions showed a marginally statistically significant decrease of 25 percent (p=0.0856) for E20 compared to E10 and statistically significant decreases of 47 percent (p=<0.0001) and 37 percent (p=0.0005), respectively, for Bu32 compared to E10 and E15. The blend of Bu32 also showed statistically significant decreases in particle number emissions of 50 percent (p=<0.0001) and 51 percent (p=<0.0001), respectively, compared to Bu16 and Bu24 blends. The blends of Bu16 and Bu24 showed statistically significant increases in particle number emissions of 43 percent (p=0.0062) and 46 percent (p=0.0083), respectively, whereas Bu32 showed a statistically significant decrease of 29 percent (p=0.0274) compared to E20. For the FFVs, weighted particle number emissions for E51 and E83 showed statistically significant decreases of 55 percent (p=0.0060) and 58 percent (p=0.0011), respectively, compared to E10, while Bu55 showed a marginally statistically significant increase in particle number emissions of 76 percent (p=0.0568) compared to E83.

In addition to the weighted particle number emissions, strong differences between the fuels for the FTP or the UC cycles were also observed during the cold-start, hot-running, and hot-start phases for both the non-FFVs and FFVs. For the non-FFVs, cold-start particle number emissions showed some strong fuel trends over the UC but not over the FTP. For the UC, cold-start particle number emissions for E20 and Bu32 showed reductions of 36 percent (p=0.0685) and 41 percent (p=0.0122), respectively, compared to E10 at marginally statistically significant and statistically significant levels. Statistically significant reductions in cold-start particle number emissions were also seen for Bu32 on the order of 40 percent (p=0.0126) and 47 percent (p=0.0014), respectively, compared to Bu16 and Bu24 blends. Cold-start particle number emissions also showed increases of 56 percent (p=0.0651) and 74 percent (p=0.0161), respectively, for Bu24 compared to E15 and E20, at statistically significant and marginally statistically significant levels. Fuel Bu16 also showed a marginally statistically significant increase of 52 percent (p=0.0759) relative to E20. For the FFVs, cold-start particle number emissions for E51 and E83 showed reductions of 48 percent (p=0.0726) and 68 percent (p=0.0003), respectively, relative to E10 at marginally statistically significant and statistically significant levels. The blend of Bu55 showed a statistically significant increase in cold-start particle number emissions of 127 percent (p=0.0110) compared to E83. For the hot-running particle number emissions, for the non-FFVs, Bu32 showed statistically significant decreases of 51 percent (p=0.0073), 49 percent (p=0.0137), and 52 percent (p=0.0069), respectively, compared to E10, Bu16, and Bu24 fuels. For the FFVs, hot-running particle number emissions for E51 and E83 showed statistically significant decreases of 55 percent (p=0.0495) and 57 percent (p=0.0173), respectively, compared to E10. For the hot-start particle number emissions, for the non-FFVs, E15, E20, and Bu32 showed statistically significant reductions of 32 percent (p=0.0348), 34 percent (p=0.0166), and 67 percent (p=<0.0001), respectively, compared to E10. Fuel Bu32 also showed statistically significant reductions of 51 percent (p=<0.0001), 50 percent (p=<0.0001), 63 percent (p=<0.0001), 56 percent (p=<0.0001), and 67 percent (p=<0.0001), respectively, compared to E15, E20, Bu16, B24, and the E10/Bu8 blend. For the FFVs, hot-start particle number emissions for E51, E83, and Bu55 showed statistically significant reductions of 56 percent (p=0.0004), 59 percent (p=<0.0001), and 51 percent (p=0.0010), respectively, compared to E10.

Particle number results reported here generally decreased with the addition of ethanol and iso-butanol, implying that the presence of oxygen in the fuel was the main contributing factor for the particle number decrease by suppressing soot formation (Dutcher et al., 2011; Maricq et al., 2012; Storey et al., 2010; Storey et al., 2014; Costagliola et al., 2013). In addition to the oxygen content, particles are also strongly related to the aromatic hydrocarbons content in the fuel (Khalek et al., 2010). The addition of higher blends of ethanol and iso-butanol in gasoline decreased the fraction of aromatic hydrocarbons and therefore their propensity of forming soot. This is consistent with the findings of Wallner and Frazee (2010), which showed that the reduction in the availability of carbon in ethanol combustion decreases the potential for benzene and soot formation as the ethanol blend ratio increases. It is interesting to note that in some cases the iso-butanol blends had higher particle number emissions compared to their corresponding ethanol blends, with the exception of Bu32, which emitted the lowest particle number emissions for most vehicles. This phenomenon could be attributed to the fact that during SIDI combustion branched butanols can produce intermediate products, such as propene and butene, leading to the formation of more benzene and soot (McEnally and Pfefferle, 2005). The results of this study indicate that the degree of branching (iso-butanol versus ethanol) may have an impact on soot formation in addition to oxygen content, since the butanol blends had equivalent oxygen contents to their corresponding ethanol blends. In addition to fuel structure, the higher viscosity of butanol blends relative to ethanol blends could also have influenced particle number emissions by altering the fuel spray characteristics (Aleiferis and van Romunde, 2013).

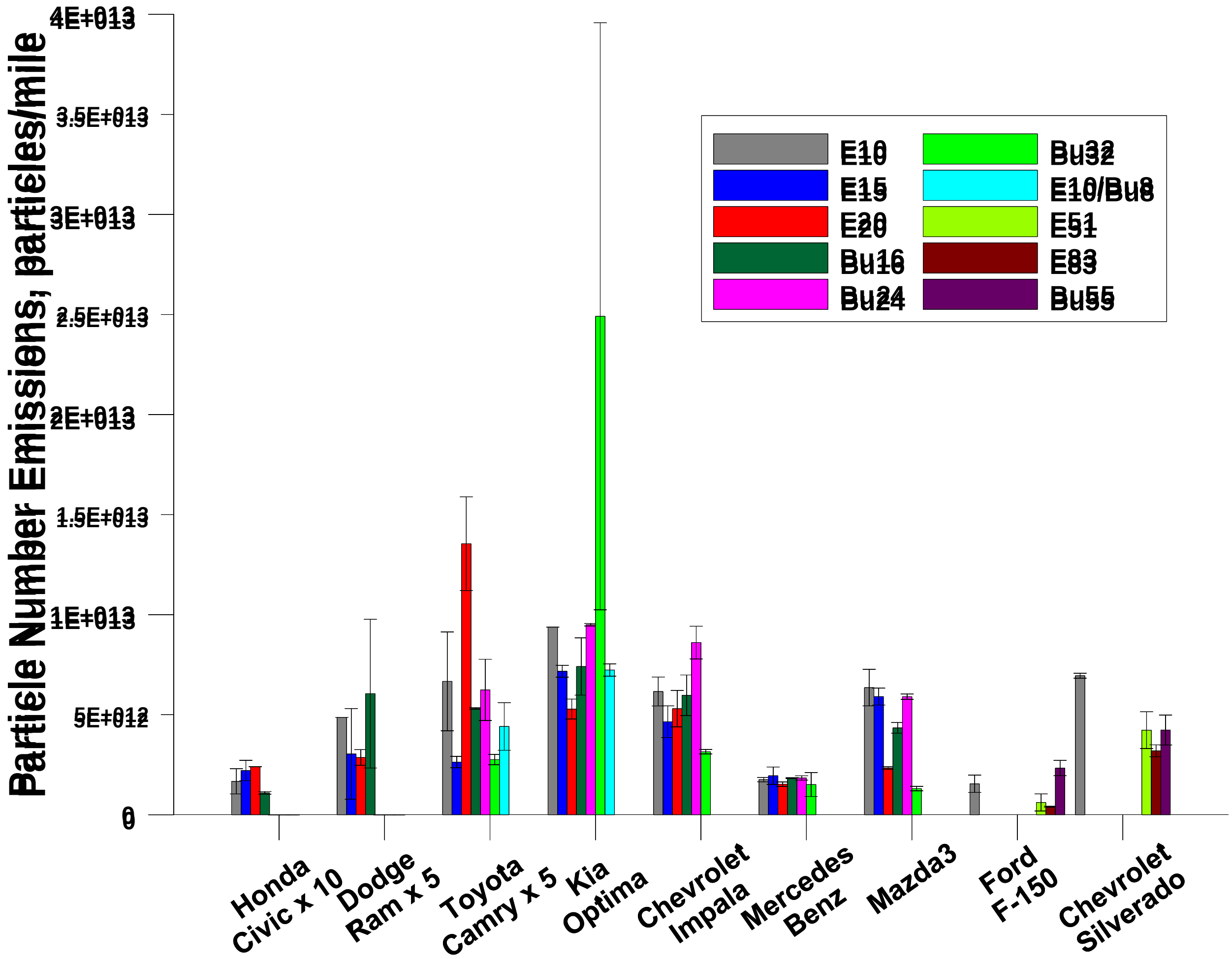
The cold-start phase for both test cycles contributes strongly to the overall particle number emissions, as the engine and catalyst are not yet at operating temperature and therefore particles consisting of volatile residues cannot be effectively oxidized. Most of the particle emissions occur towards the beginning of the FTP and UC, with roughly 60-90 percent of the particle emissions occurring in the first 200-300 seconds. More specifically, for the Honda Civic, fuel average particle number counts for cold-start, hot-running emissions, and hot-start were 3.46×10^{11}, 9.14×10^{10}, and 4.62×10^{10} #/mile for the FTP and 9.52×10^{11}, 1.42×10^{11}, and 9.67×10^{10} #/mile for the UC, respectively. For the Dodge Ram, fuel average particle number counts by bag were 1.48×10^{12}, 2.52×10^{11}, and 2.40×10^{11} #/mile for the FTP and 2.59×10^{12}, 6.77×10^{11}, and 3.01×10^{11} #/mile for the UC, respectively. For the Toyota Camry fuel average particle number counts by bag were 1.75×10^{11}, 2.58×10^{10}, and 3.26×10^{10} #/mile for the FTP and 1.58×10^{12}, 1.19×10^{11}, and 3.10×10^{10} #/mile for the UC, respectively. For the Kia Optima, fuel average particle number counts by bag were 1.95×10^{13}, 3.82×10^{12}, and 2.64×10^{12} #/mile for the FTP and 4.44×10^{13}, 8.72×10^{12}, and 3.57×10^{12} #/mile for the UC, respectively. For the Chevrolet Impala, fuel average particle number counts by bag were 1.91×10^{13}, 1.39×10^{12}, and 9.40×10^{11} #/mile for the FTP and 4.60×10^{13}, 3.50×10^{12}, and 1.09×10^{12} #/mile for the UC, respectively. For the Mercedes Benz, fuel average particle number counts by bag were 9.45×10^{12}, 8.98×10^{10}, and 2.81×10^{11} #/mile for the FTP and 1.98×10^{13}, 7.96×10^{11}, and 1.63×10^{11} #/mile for the UC, respectively. For the Mazda3, fuel average particle number counts by bag were $1.69x10^{13}$, $2.95x10^{12}$, and $2.03x10^{12}$ #/mile for the FTP and $3.54x10^{13}$, $2.68x10^{12}$, and $2.51x10^{12}$ #/mile for the UC, respectively. For the Ford F-150, fuel average particle number counts by bag were $1.54x10^{12}$, $6.45x10^{11}$, and $2.26x10^{11}$ #/mile for the FTP and $4.28x10^{12}$, $1.12x10^{12}$, and $2.11x10^{11}$ #/mile for the UC, respectively. For the Chevrolet Silverado, fuel average particle number counts by bag were $1.22x10^{13}$, $1.44x10^{13}$, and $2.74x10^{12}$ #/mile for the FTP and $3.07x10^{13}$, $3.10x10^{12}$, and $4.99x10^{12}$ #/mile for the UC, respectively. The cold-start emissions for the UC are substantially higher compared to those of the FTP, because the cold-start phase for the FTP is about ~200 seconds longer than that for the UC, and hence includes some driving after the initial spike in cold-start emissions has ended. The sharp increases in particle number emissions for the SIDI vehicles during cold-start could be due to fuel accumulation onto the cold piston and cylinder surfaces. The significant reduction in particle number emissions after the cold-start can be attributed to the higher intake air temperatures, fuel temperatures, and piston surface temperatures, which promote fuel vaporization and thus better fuel-air mixing, coupled with the higher efficiency of the TWC once it has reached its light-off temperature (He et al., 2012). Hot-running and hot-start particle emissions for the FTP did not show significant differences, in contrast to the trends for the UC. For the UC, hot-start particle emissions were systematically lower than those for either the cold-start or hot-running phases due to much less over-fueling than for the cold-start and a driving schedule is much milder than in the hot-running phase.

Figure 24: Particle Number Emissions for All Vehicle/Fuel Combinations Over the FTP Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 25: Particle Number Emissionsfor All Vehicle/Fuel Combinations Over the UC Cycle



Errors bars represent ± one standard deviation around the average value for each fuel.

The real-time traces of particle number emissions over the FTP give some insight on the formation mechanism, as shown in Figure 26. For comparison purposes, real-time particle number emissions are provided for one PFI vehicle (Toyota Camry), one wall-guided SIDI vehicle (Mazda3), and one spray-guided SIDI vehicle (Mercedes Benz) on the reference E10 blend. For the PFI vehicle, particles are mainly formed during the first 200-250 seconds of the FTP cycle (cold-start phase), during which more than approximately 70 percent of the total emitted particles may be produced. Elevated particle number emissions were also observed during short periods that coincide with vehicle acceleration (i.e., some particle number peaks during sharp accelerations for the hot-start phase). The spray-guided vehicle showed similar particle number profile to the PFI vehicle, with the cold-start phase dominating the particle number emissions. For the wall-guided SIDI vehicle, particles are produced over the entire duration of the cycle, with the cold-start phase also having somewhat higher particle number emissions. It is worth noting that the particle number emissions for the wall-guided SIDI vehicle do not appear as spikes during accelerations as they did for the PFI vehicle. However, for all vehicle types, the vast majority of particles are produced during vehicle accelerations. The more aggressive the acceleration, the higher the concentration of particles produced.

Figure 26: Real-Time Particle Number Emissions for the PFI Toyota Camry, Wall-Guided SIDI Mazda3, and Spray-Guided SIDI Mercedes Benz Over the FTP on E10

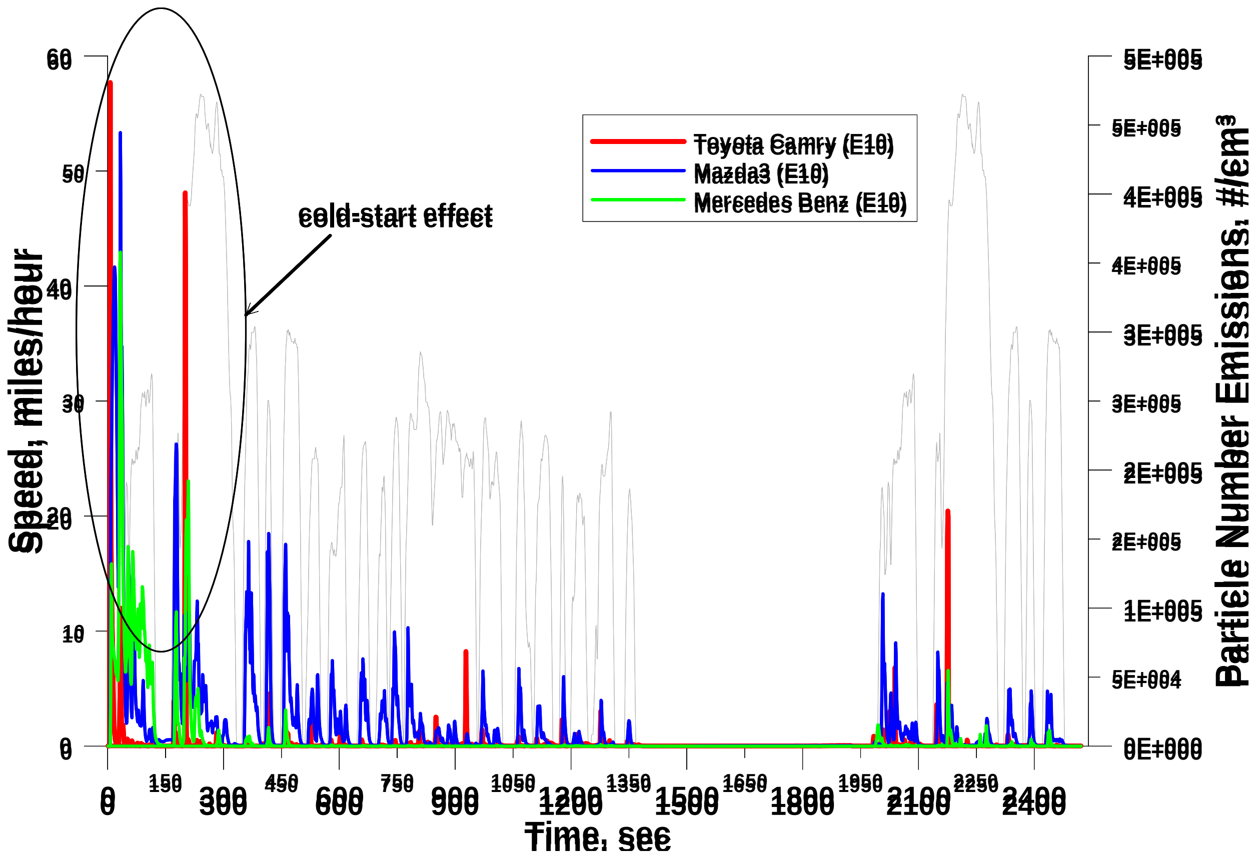
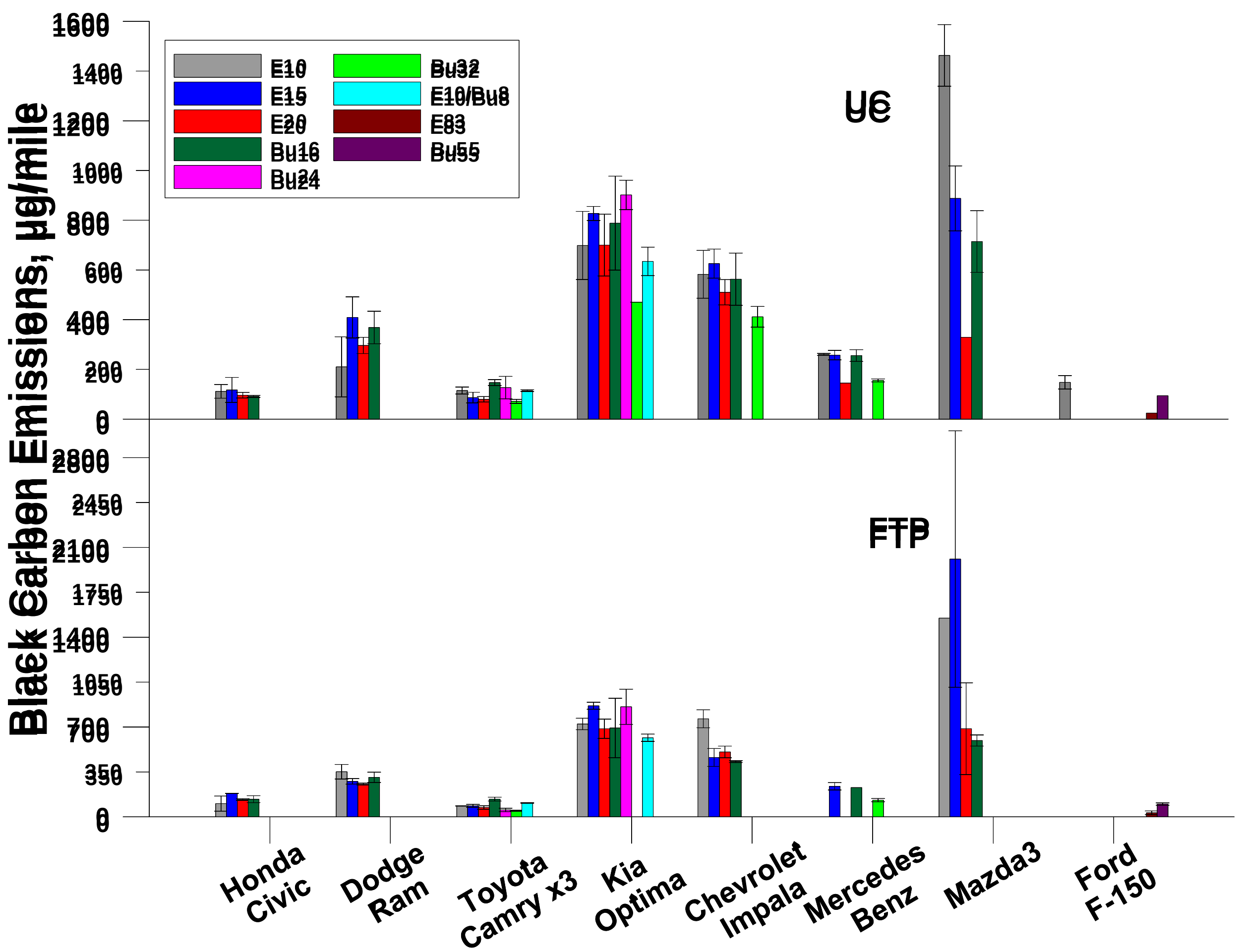


Figure 27 shows the black carbon emissions, expressed in μg/m³, for all vehicle/fuel combinations over the FTP and UC. It should be mentioned that the MAAP wasn't available for a number of vehicle/fuel combinations during the test campaign. Black carbon concentration is an operationally defined quantity that corresponds to the extent to which particles deposited on a filter absorb light. Black carbon is generally formed through incomplete combustion and it has recently become of a higher priority to regulatory and environmental agencies since black carbon makes an important contribution to global warming in addition to the known greenhouse gases. Besides its direct influence on the climate, black carbon also adversely effects visibility, human health, and act as a cloud condensation nuclei (Bond et al., 2013). It has been suggested that reducing black carbon emissions via reductions in black carbon number concentration will result in a decrease in global cloud radiative forcing (Jiang et al., 2005). Overall, the black carbon results were mixed and did not follow a uniform trend for both test cycles. Clearly, black carbon emissions were 3 to 7 times higher for the SIDI vehicles compared to PFI vehicles, suggesting that SIDI PM were primarily elemental carbon or soot in nature. The PM from the PFI vehicles is more organic in nature (Maricq et al., 2012). For the FTP, black carbon reductions with increasing alcohol concentration were seen for the Dodge Ram, Toyota

Camry, Chevrolet Impala, and Mazda3. For the UC, some reductions in black carbon emissions were seen for the Toyota Camry, Mercedes Benz, and Mazda3, with the Dodge Ram showing increases in black carbon with the higher alcohol fuels, and the Kia Optima and the Chevrolet Impala insignificant differences. The reductions in black carbon emissions could be attributed to the higher oxygen content in the fuel, which can reduce the tendency to form soot. A relatively good correlation was found for black carbon and particle number emissions for the PFI vehicles, especially for the FTP, although the correlation was not strong for the UC or the SIDI vehicles. It is also interesting to note that most of the black carbon emissions occurred during the cold-start phases of the FTP and UC, due to the reduced fuel vaporization and wall impingement, and the reduced efficiency of the TWC. These findings are in agreement with those of a recent chassis dynamometer study on light-duty gasoline vehicles (Forestieri et al., 2013).

Figure 27: Black Carbon Emissions for the FTP (bottom panel) and UC (top panel) Test Cycles



Errors bars represent ± one standard deviation around the average value for each fuel.

3.6 Particle Size Distributions

Real-time particle size distributions were obtained with an EEPS over the FTP and UC test cycles. The EEPS wasn't available through the entire course of this study and, therefore, real-time particle size distributions were only obtained for the SIDI passenger cars and the FFVs. Figure 28 through Figure 35 presents the particle size distributions for the SIDI passenger cars over the FTP and UC test cycles. Overall, the fuel effect was noticeable in particle size distributions for most vehicles, with the higher oxygen content blends exhibiting decreases in particle number. The majority of vehicles showed marked reductions in accumulation mode particles with E20 and Bu32 blends, while Bu32 generally shifted towards smaller particle diameters than E20. Some trends were also seen for lower accumulation mode particles with decreasing aromatics content. These results suggest that the sooting tendency decreases with increasing oxygen content and decreasing aromatics.

In general, the SIDI vehicles displayed diesel-like distributions that were bimodal in nature. The particle size distributions for all test fuels were dominated by the accumulation mode particles, which are formed by agglomeration of nucleation mode particles and may also include condensed or adsorbed volatile material. This finding is consistent with previous studies conducted with SIDI vehicles on oxygenated fuel formulations (Storey et al., 2010; Storey et al., 2012; Khalek et al., 2010). The accumulation mode geometric number mean diameter for all fuels and most vehicles ranged from ~60 nm to 90 nm. For all vehicles, nucleation mode particles were found at very low concentrations and peaked at around 11 nm in diameter. Interestingly, the SIDI Kia Optima on Bu32 blend exhibited a sharp bimodal size distribution profile for the UC, but not for the FTP cycle. It should be noted that this vehicle was the only one among the SIDI passenger cars that showed high concentrations of nucleation mode particles in the exhaust. The higher concentrations of nucleation mode particles could be responsible for the higher total particle number emissions observed with this vehicle on Bu32 over the UC cycle.

The peak number concentrations for the wall-guided SIDI vehicles were substantially higher than those of the spray-guided SIDI vehicle, with the Kia Optima having the highest concentration of accumulation mode particles followed by the Chevrolet Impala, and Mazda3. This can be attributed to the fact that there will be more localized fuel-rich zones in the charge cloud due to the reduced mixture preparation time associated with wall-guided engine architectures. This result somewhat correlates with the relatively lower PM mass, particle number, and black carbon emissions found for the spray-guided Mercedes Benz compared to the wall-guided SIDI vehicles.

Figure 28: Average Particle Size Distribution Results for the Kia Optima Over the FTP Cycle

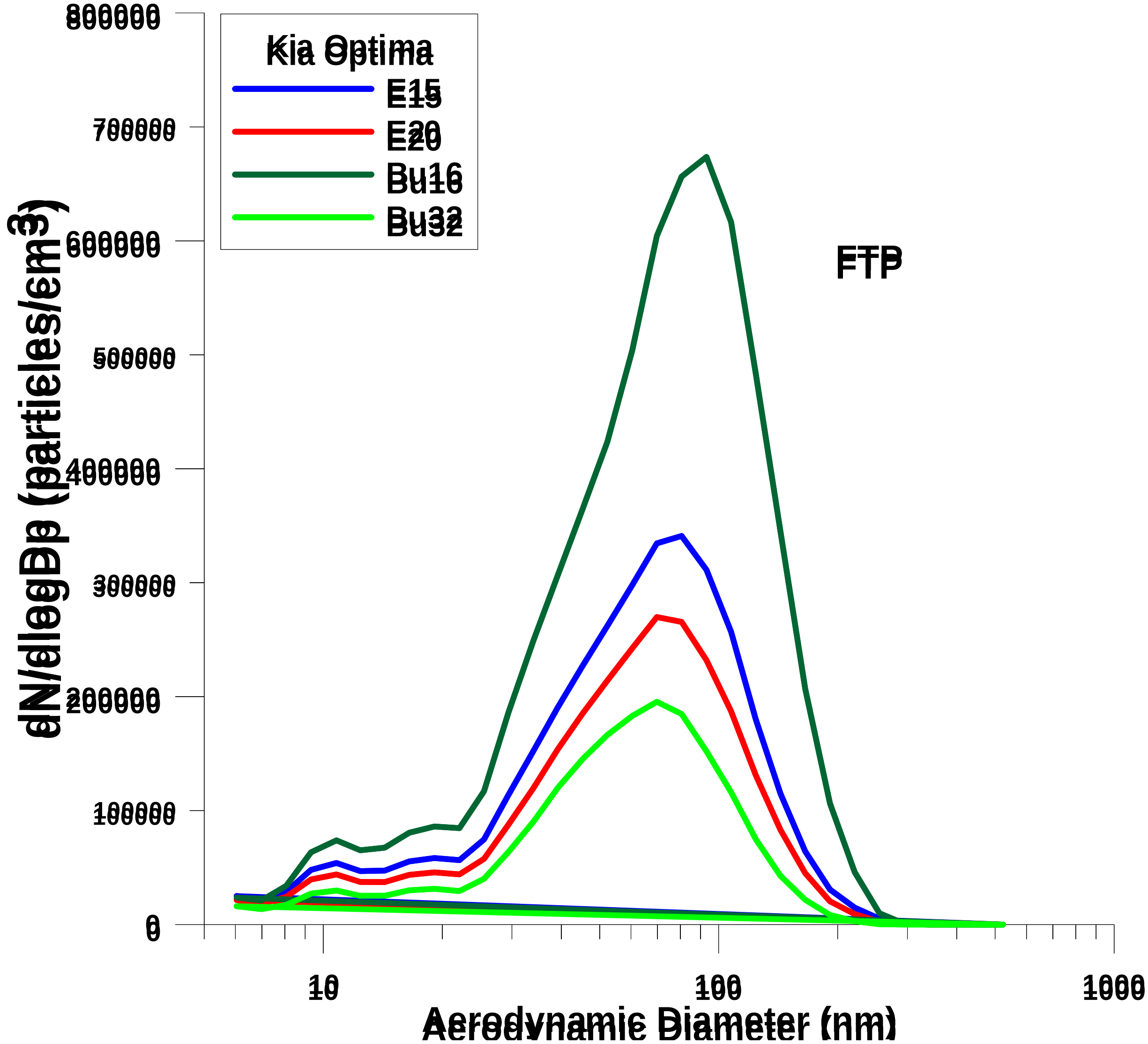


Figure 29: Average Particle Size Distribution Results for the Kia Optima Over the UC Cycle

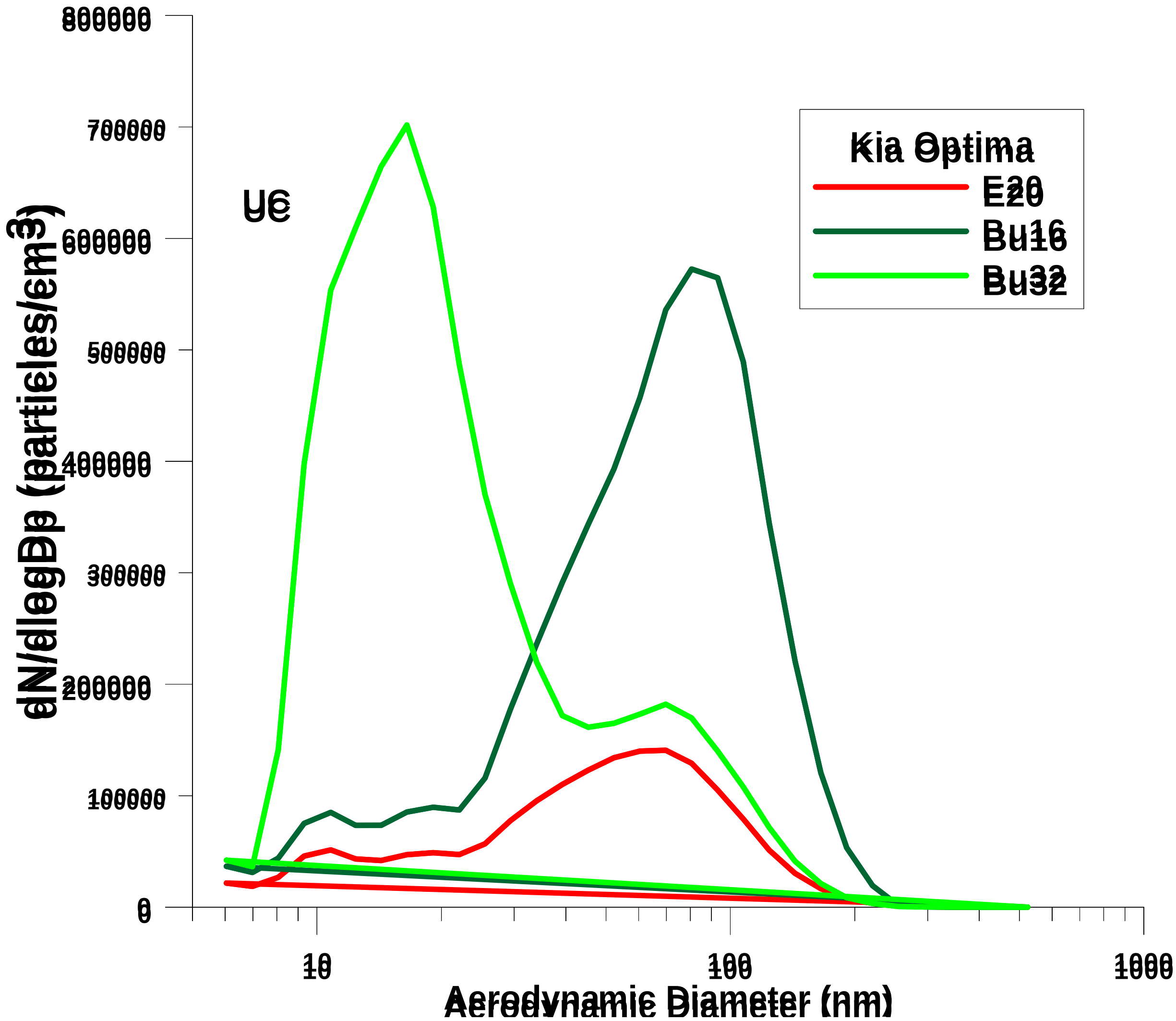


Figure 30: Average Particle Size Distribution Results for the Chevrolet Impala Over the FTP Cycle

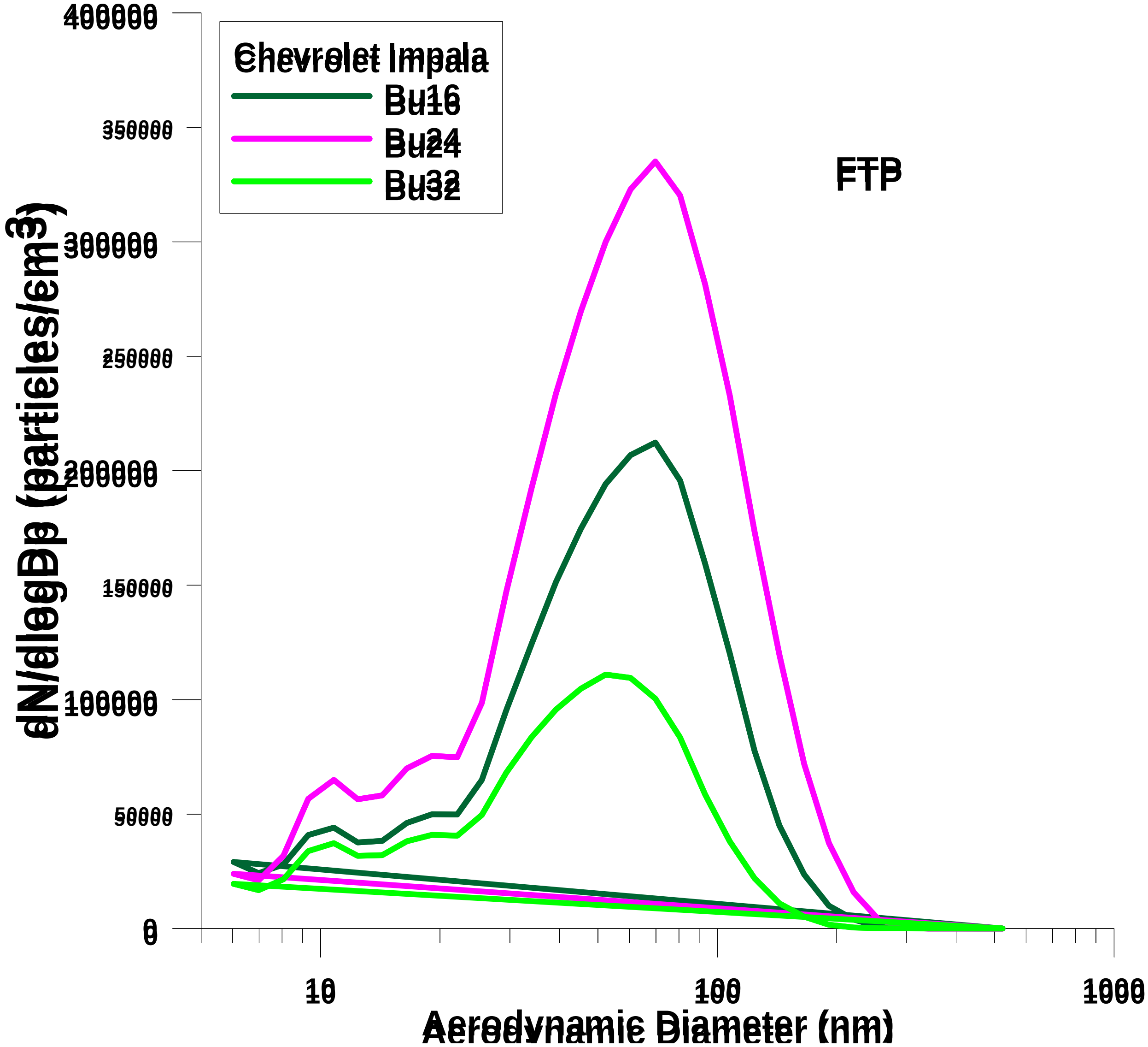


Figure 31: Average Particle Size Distribution Results for the Chevrolet Impala Over the UC Cycle

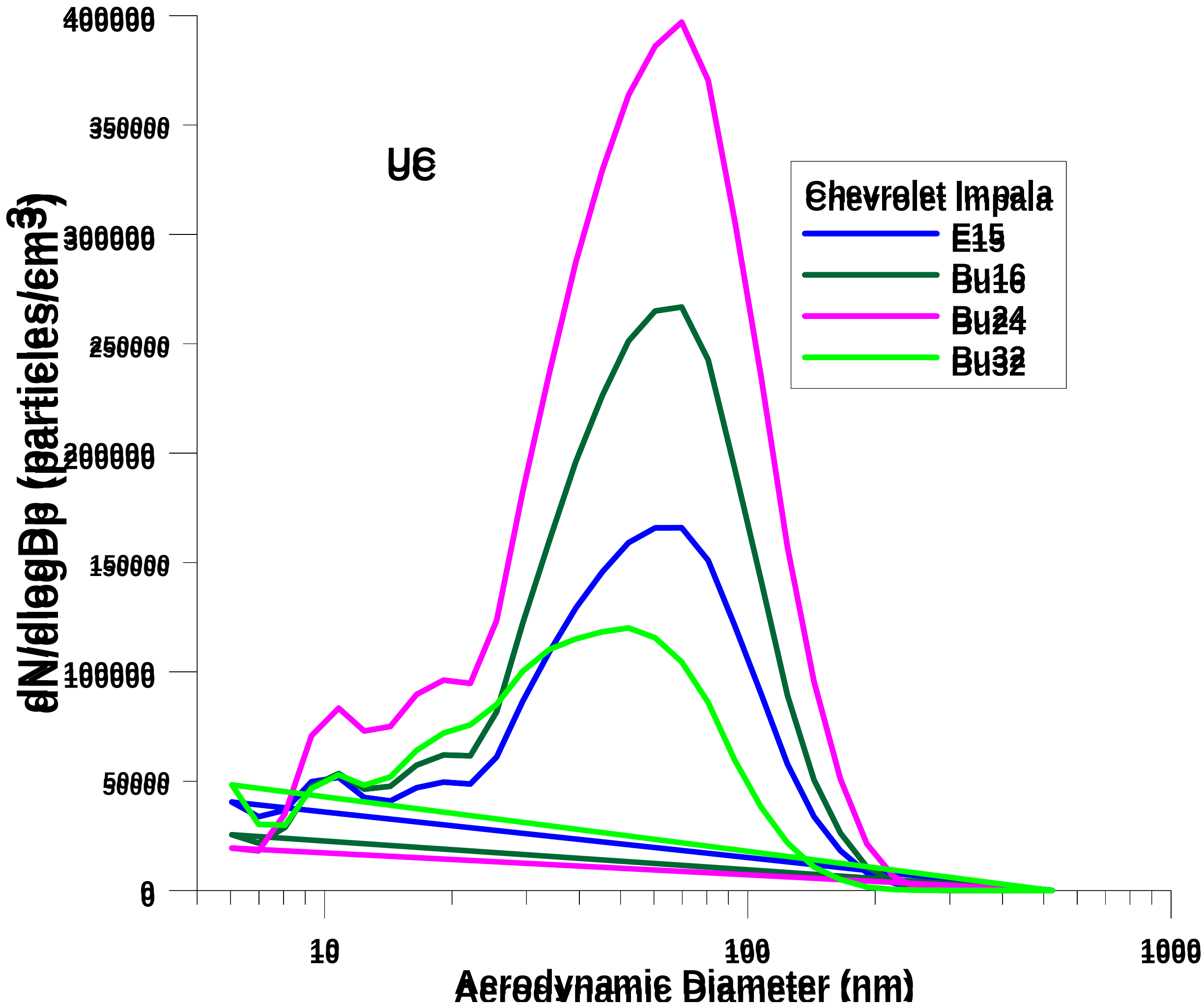


Figure 32: Average Particle Size Distribution Results for the Mercedes Benz Over the FTP Cycle

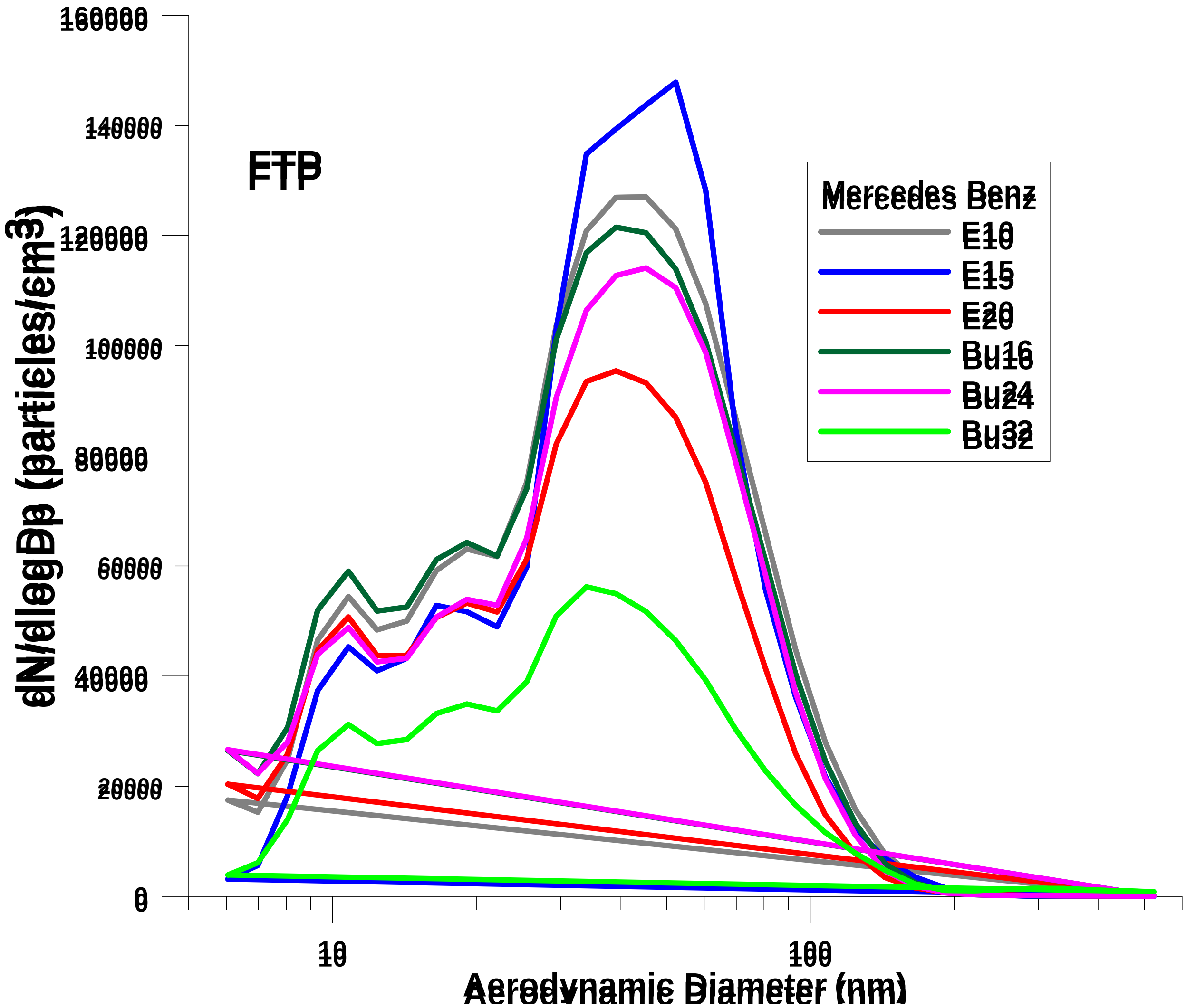


Figure 33: Average Particle Size Distribution Results for the Mercedes Benz Over the UC Cycle

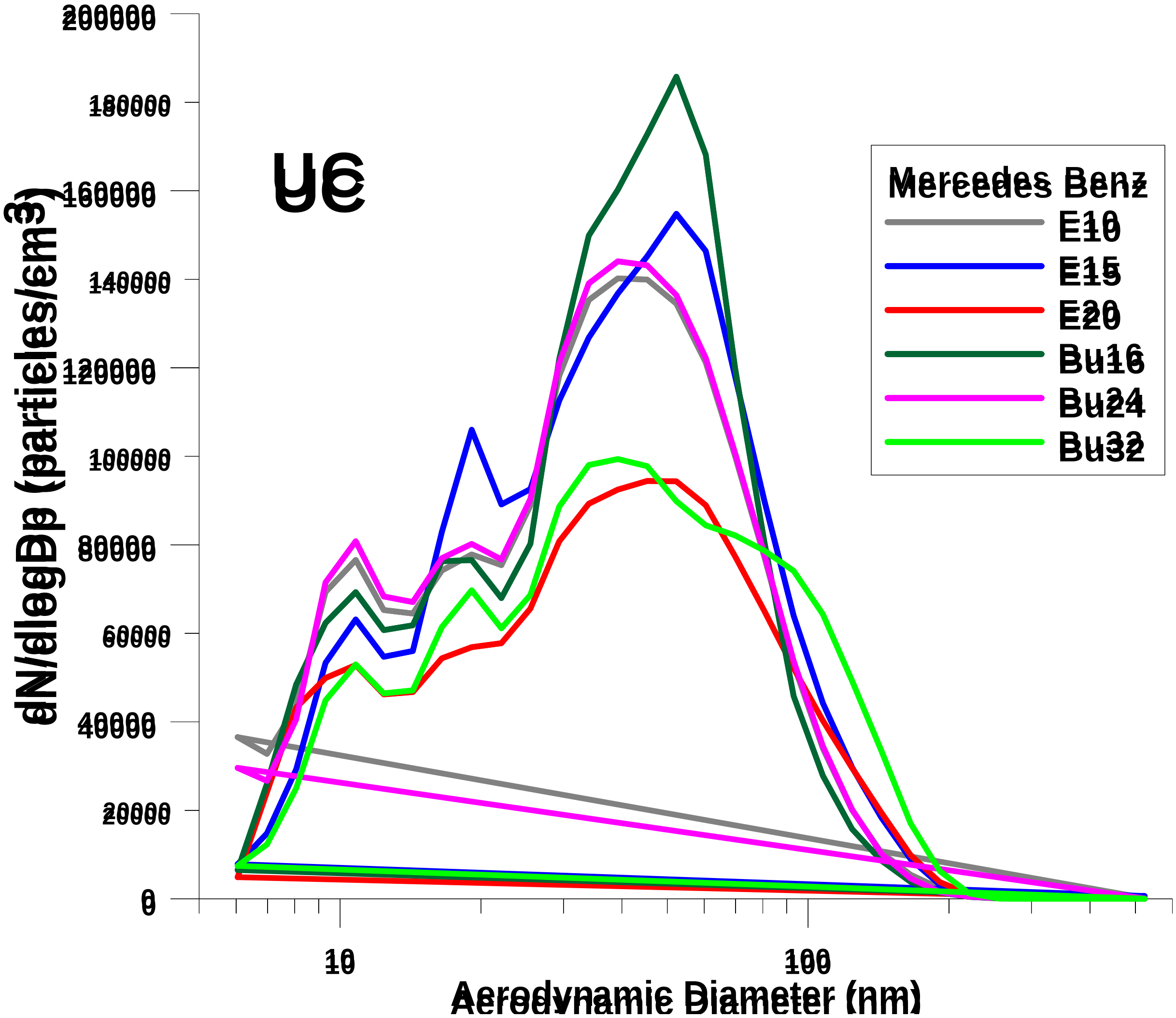


Figure 34: Average Particle Size Distribution Results for the Mazda3 Over the FTP Cycle

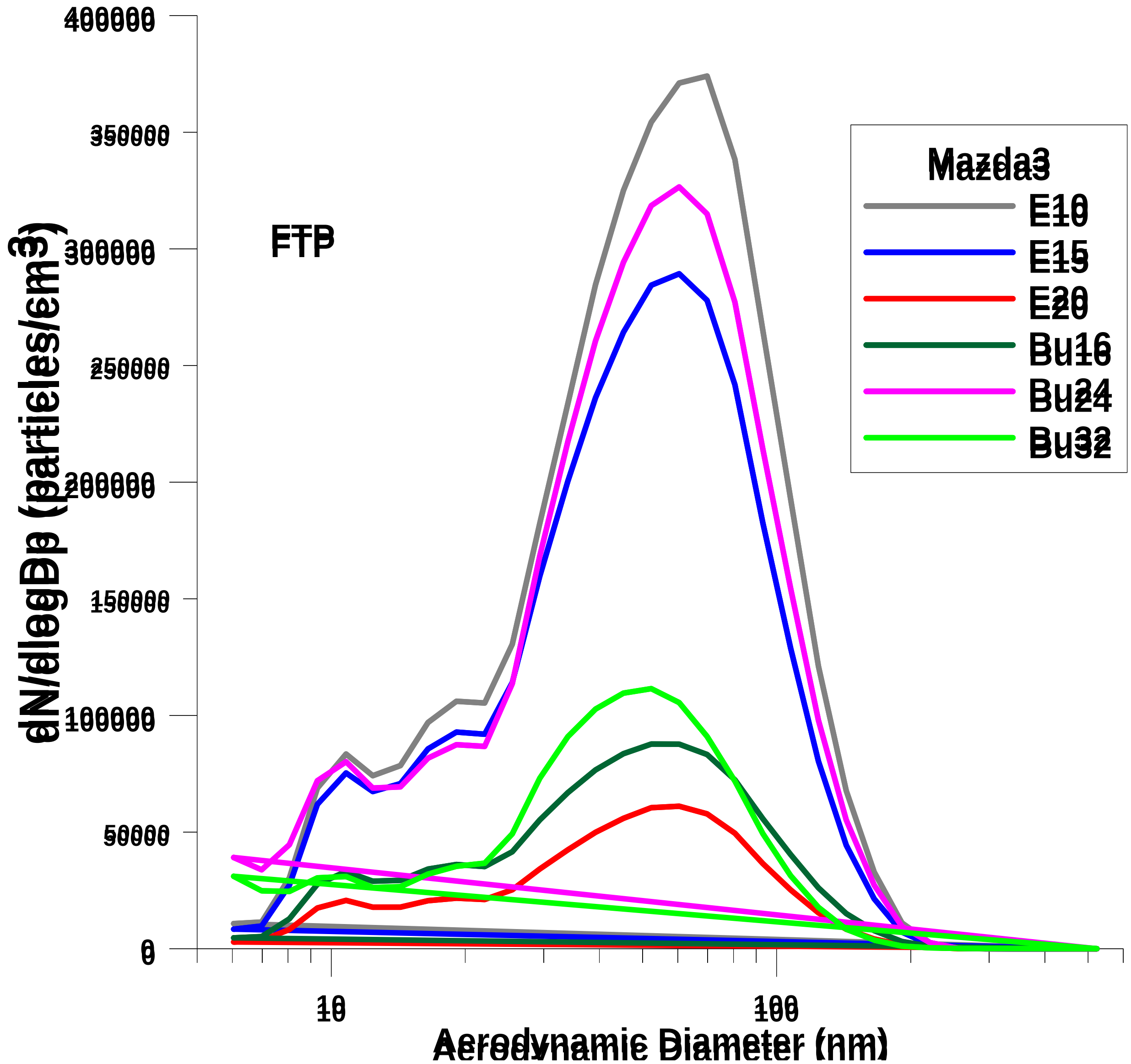


Figure 35: Average Particle Size Distribution Results for the Mazda3 Over the UC Cycle

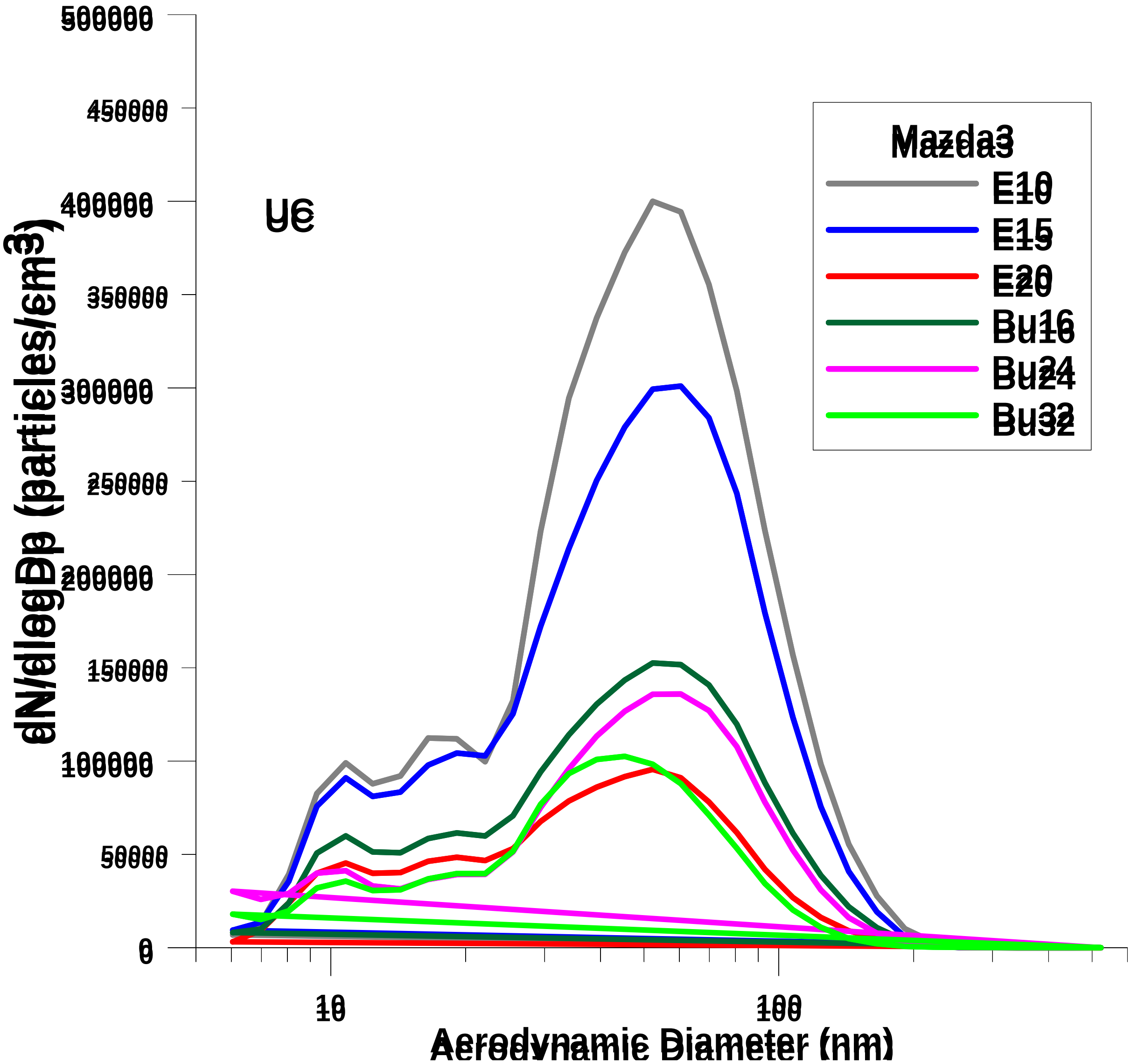


Figure 36 through Figure 39 present the particle size distributions for the FFVs over the FTP and UC test cycles on all four fuels. For the Ford F-150, the particle size distributions profile for both test cycles was quite unstable with no clear peak, especially for E83 and Bu55 blends. Most fuels showed emissions of nucleation mode particles in the size range of 10-30 nm, with the exception of E10 that showed a decidedly bimodal particle size distribution with nucleation mode particles peaking at 11 nm for both cycles and accumulation mode particles in the size range of 53 nm and 93 nm, respectively, for FTP and UC. The Chevrolet Silverado displayed a diesel-like bimodal distribution with the accumulation mode dominating the particle size distribution. The accumulation mode geometric mean particle diameter ranged from 34 nm (E83) to 93 nm (E10) for the FTP and from 34 nm (E83) to 70 nm (E10) for the UC. The peak particle size of the nucleation mode centered near 11 nm for both cycles.

The fuel impact on particle size distributions was particularly clear with the high oxygen content low aromatics content blends showing lower number concentrations of accumulation mode particles. The higher oxygen/lower aromatic content E51, E83, and Bu55 systematically showed lower number concentrations of accumulation mode particles, and a smaller size in geometric mean diameter compared to E10. It is assumed that the oxygen content in the blends contributed to lower formation rate of soot, thus reducing the number of accumulation mode particles. In addition, the lower combustion temperatures with increasing alcohol content in gasoline could have some influence on the reduction in accumulation mode particles with higher ethanol blends. Under these conditions, primary carbon particles formed by thermal pyrolysis and dehydrogenation reactions of fuel usually decrease. Previous studies in premixed ethanol flames have shown decreases in the amount of soot precursors and a slowdown in the growth process of particles (Maricq, 2012; Salamanca et al., 2012). In addition, the water formed by the pyrolysis of ethanol can modify the mechanism of radical formation by decreasing the quantity of soot precursors and the total amount of soot (Salamanca et al., 2012).

Figure 36: Average Particle Size Distribution Results for the Ford F-150 Over the FTP Cycle

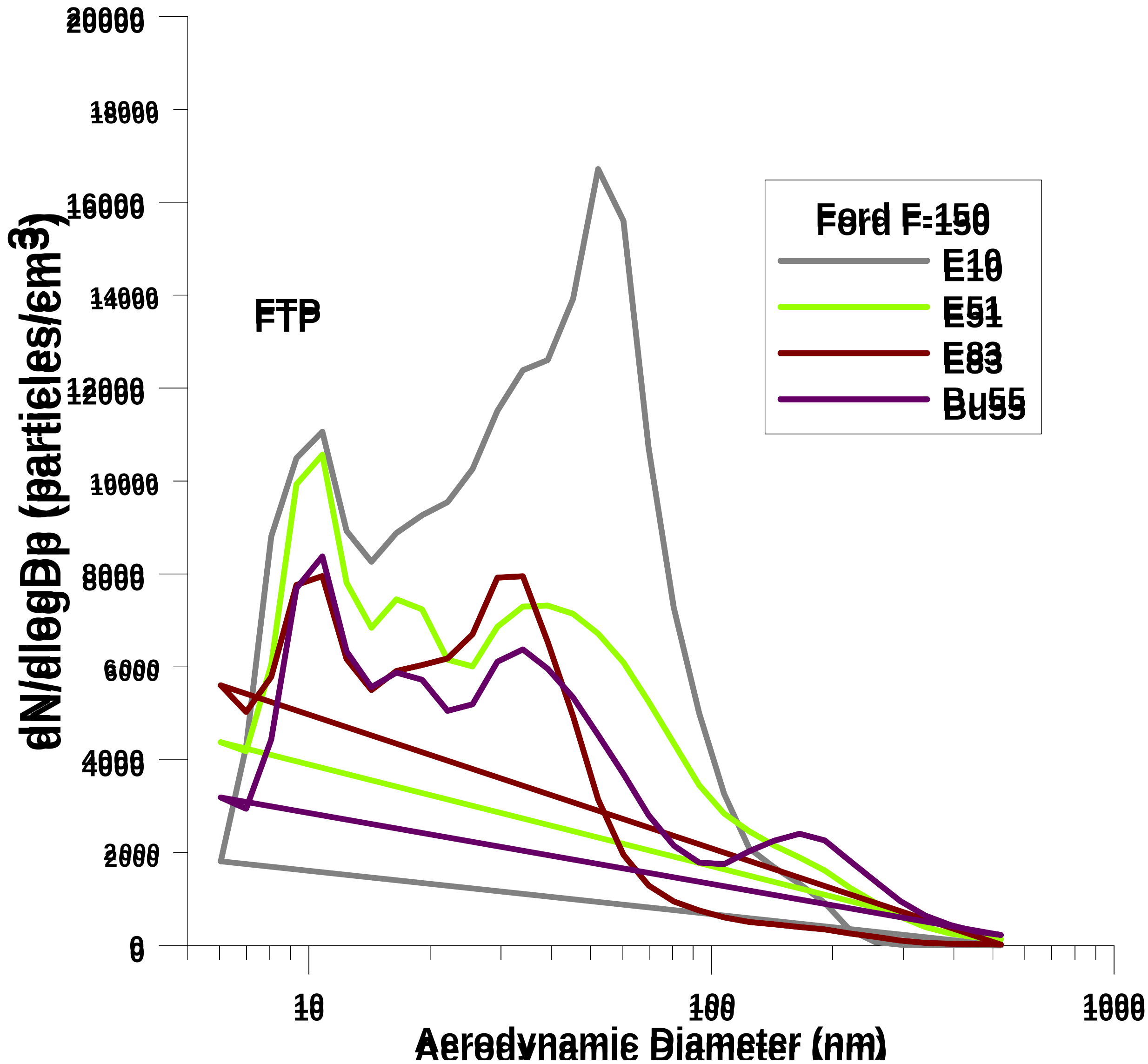


Figure 37: Average Particle Size Distribution Results for the Ford F-150 Over the UC Cycle

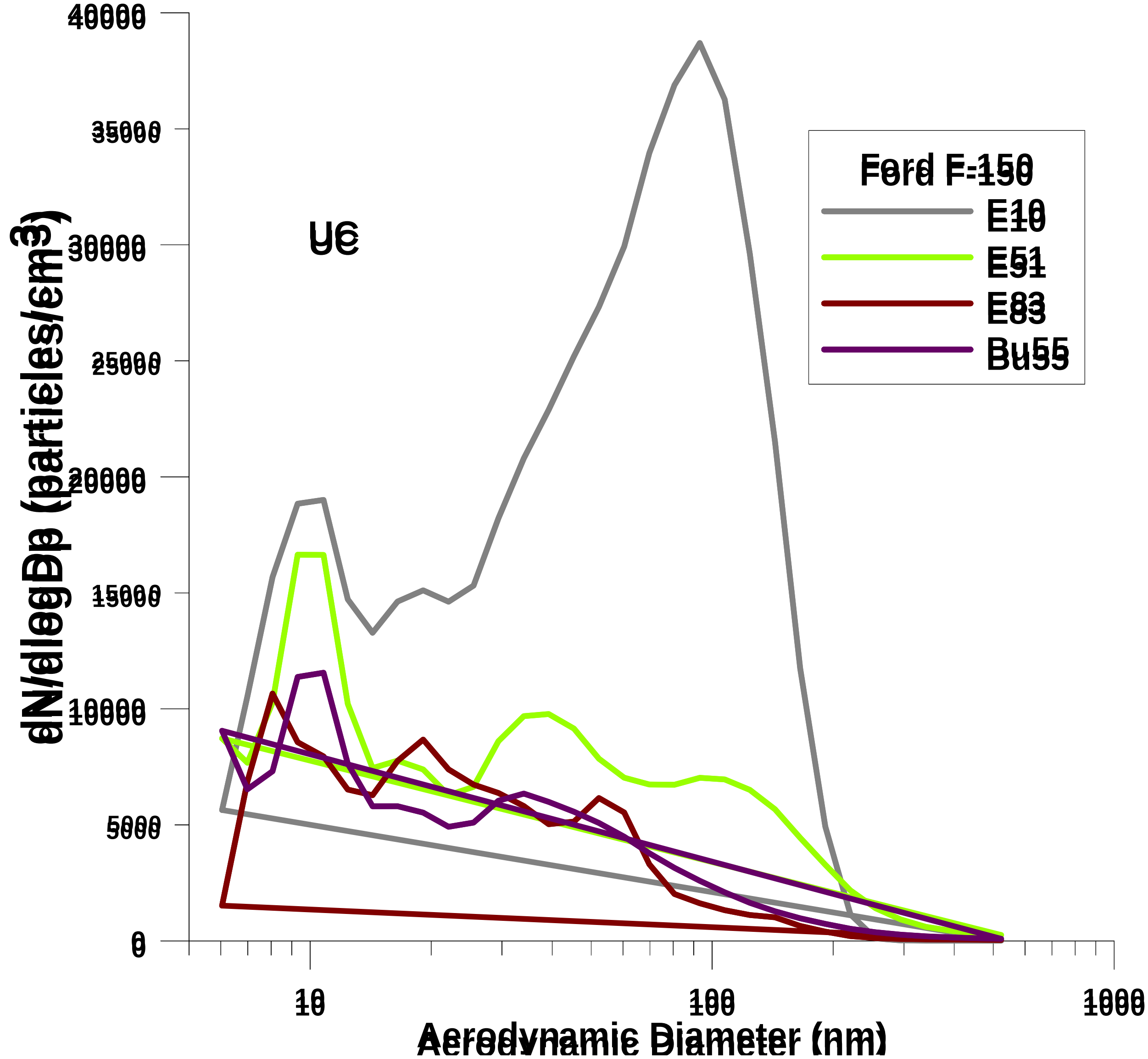


Figure 38: Average Particle Size Distribution Results for the Chevrolet Silverado Over the FTP Cycle

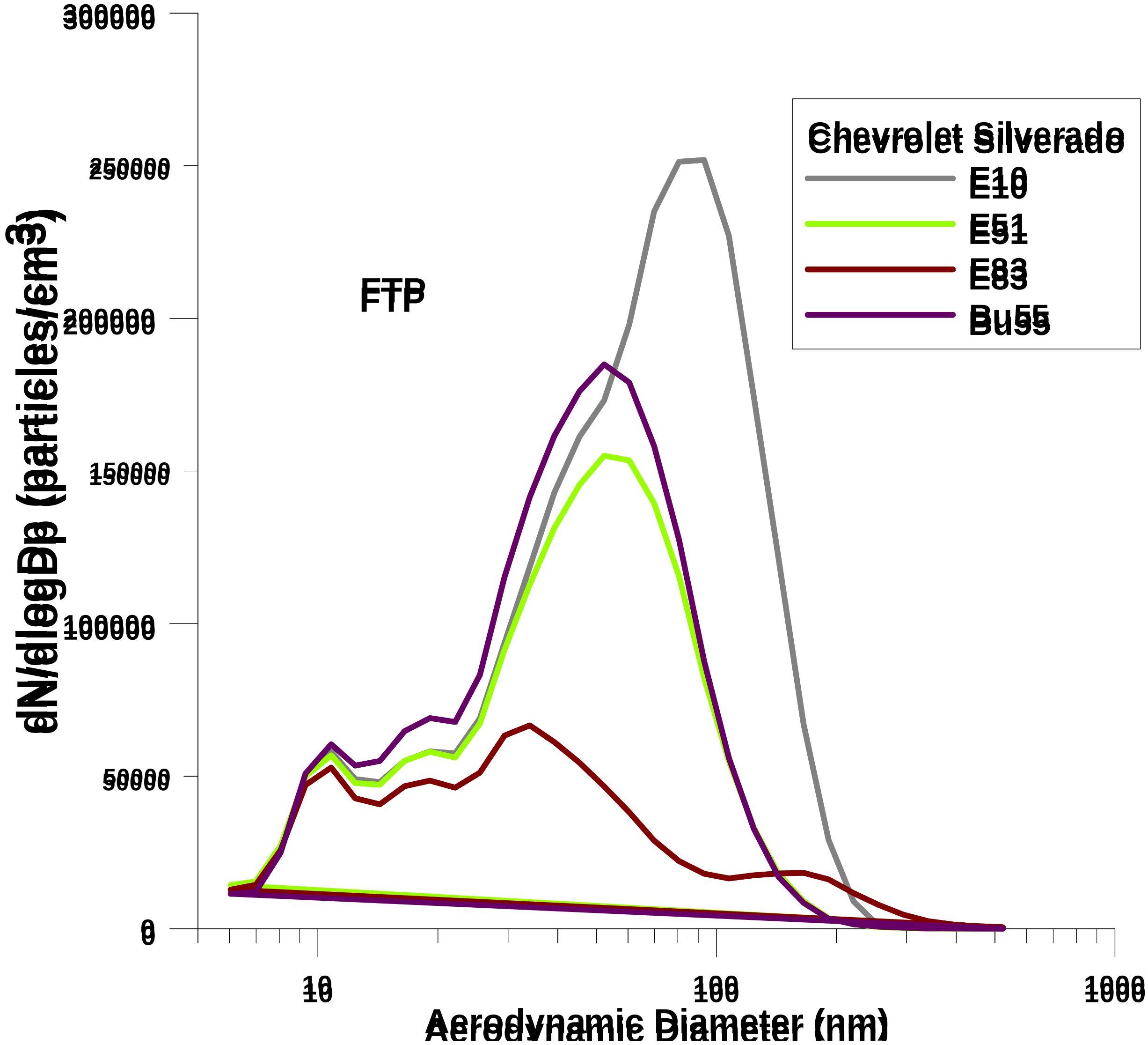
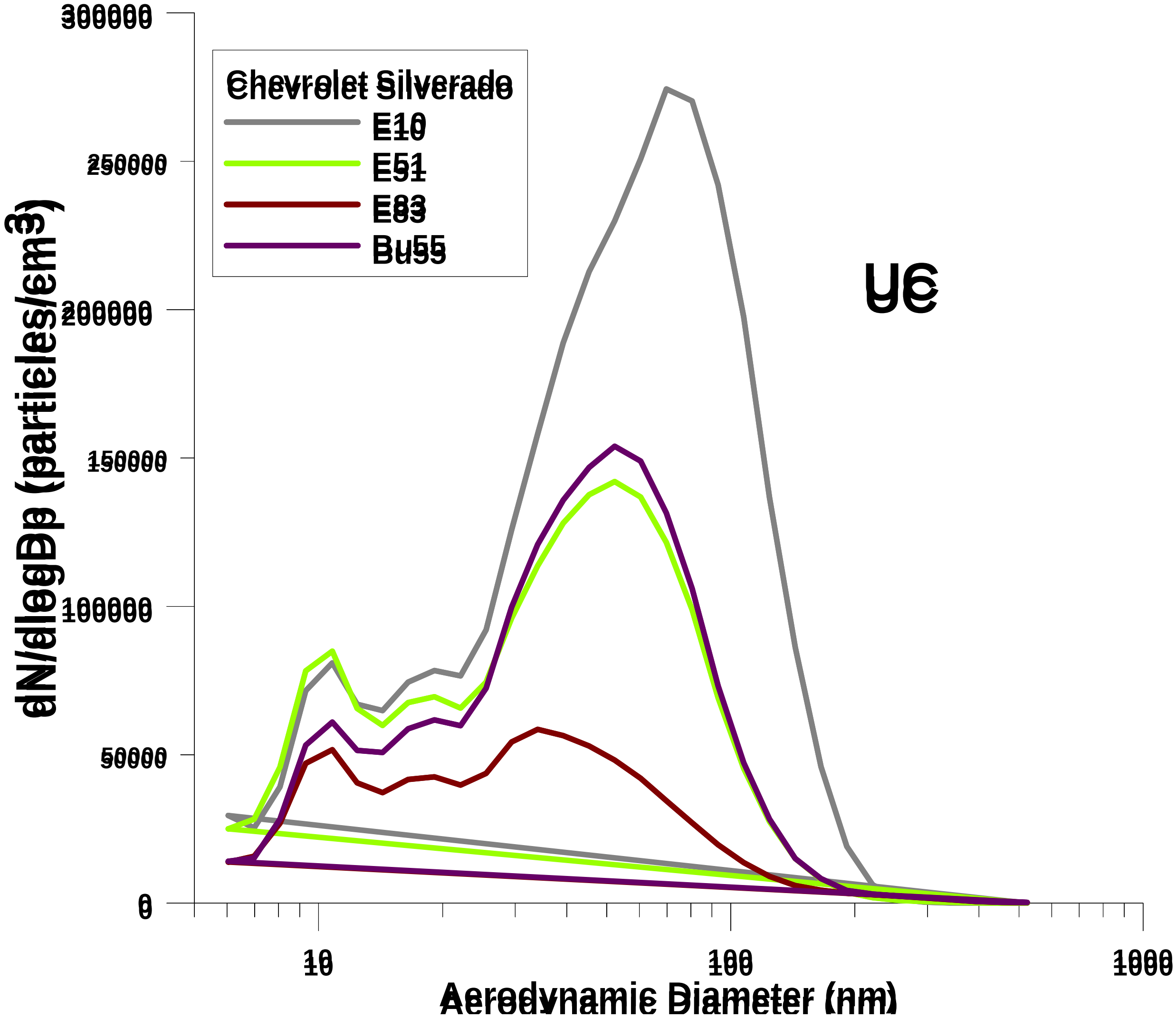


Figure 39: Average Particle Size Distribution Results for the Chevrolet Silverado Over the UC Cycle



3.7 Carbonyl Emissions

Carbonyl compounds are displayed in Figure 40 through Figure 43. For better representation of the results, the vehicles have been grouped based on their type. Figure 40 through Figure 43 show the carbonyl emissions for the PFI passenger cars, for the SIDI Kia Optima and SIDI Chevrolet Impala, for the SIDI Mercedes Benz and SIDI Mazda3, and for the FFVs, respectively. It should be emphasized that carbonyl emissions were only measured over the FTP cycle. For all vehicle/fuel combinations, low molecular-weight aldehydes such as formaldehyde and acetaldehyde were the most abundant compounds in the tailpipe followed by butyraldehyde, benzeldehyde, propionaldehyde, crotonaldehyde, and methacrolein. Previous studies have also shown that lighter aldehydes, such as formaldehyde and acetaldehyde, were the dominant carbonyl compounds in vehicle exhaust (Graham et al., 2008; Grosjean et al., 2001; Karavalakis et al., 2012; Ratcliff et al., 2013).

The results showed that total carbonyl emissions for E20 and Bu16 were higher than those of E10. Total carbonyls were 1.073±0.188 and 3.440±0.426 mg/mile for E20, and 1.048±0.213 and 2.318±0.631 mg/mile for Bu16 compared to 0.889±0.178 and 1.855±0.464 mg/mile for E10, for the Honda Civic and the Dodge Ram, respectively. For the Toyota Camry, on the other hand, the differences in total carbonyls for the ethanol and butanol blends were small. For the Kia Optima, total carbonyls for Bu16 (0.742±0.341), Bu24 (1.040±0.772), and E10/Bu8 (1.429±0.685) were higher than those measured for E15 (0.561±0.261) and E20 (0.287±0.168). For the Chevrolet Impala, total carbonyls for E20 (1.203±0.644) were higher than those of E10 (0.884±0.173) and E15 (0.696±0.647), while Bu16 (0.988±0.842) showed higher total carbonyls compared to both E10 and E15, and Bu32 (0.723±0.327) showed higher total carbonyls compared to E15. For the Mercedes Benz, total carbonyls for Bu24 (0.994±0.243) and Bu32 (2.329±0.903) were higher than for the E10 (0.768±0.134), E15 (0.744±0.424) and E20 (0.779±0.232) blends. For the Mazda3, total carbonyls were higher for E20 (1.173±0.602) and Bu16 (1.434±0.396) as compared to E10 (1.003±0.383), whereas Bu24 (0.754±0.353) and Bu32 (0.797±0.253) blends showed lower total carbonyl emissions relative to E10. Overall, the results indicate that in most cases higher ethanol blends and butanol blends are more reactive than E10 during combustion.

For this study, a comprehensive statistical analysis was conducted to identify the fuel effects on the emissions of formaldehyde, acetaldehyde, and butyraldehyde. For the non-FFVs, the fuel blends did not show any statistically significant effect on formaldehyde and acetaldehyde emissions. Our results showed both increases and decreases in both aldehydes for most vehicles without consistent trends. For the FFVs, on the other hand, the fuel impact on carbonyl emissions was particularly strong, especially for acetaldehyde emissions. For formaldehyde emissions, there were some increases for the PFI Ford F-150 with the higher alcohol fuels, but not for the SIDI Chevrolet Silverado. Marginally statistically significant differences in formaldehyde emissions were only seen for Bu55, which increased on the order of 49 percent (p=0.0957) compared to E51. As expected, acetaldehyde emissions showed stronger effects between fuels for the FFVs, especially for the higher ethanol blends. For acetaldehyde emissions, E51 and E83 showed statistically significant increases of 380 percent (p=<0.0001) and 580 percent (p=<0.0001), respectively, compared to E10, while Bu55 exhibited statistically significant reductions in acetaldehyde emissions of 79 percent (p=<0.0001) and 85 percent (p=<0.0001), respectively, compared to E51 and E83 blends.

High molecular weight aldehydes, including benzaldehyde, crotonaldehyde, and propionaldehyde, were not included in the statistical analysis. These compounds showed both increases and decreases with higher ethanol and iso-butanol blends for the conventional PFI and SIDI vehicles and the FFVs. For benzaldehyde emissions, in general, the higher oxygen content/lower aromatics blends resulted in lower emissions than E10, without this trend being consistent. It was also appeared that higher concentration of iso-butanol favored the formation pathway of propionaldehyde compared to ethanol blends. This phenomenon was more pronounced for the FFVs where the use of Bu55 led to sharp increases in propionaldehyde emissions relative to ethanol fuels. Overall, methacrolein emissions trended lower with higher ethanol and butanol blends with some exceptions, indicating that neither ethanol nor butanol participate in the formation of this pollutant.

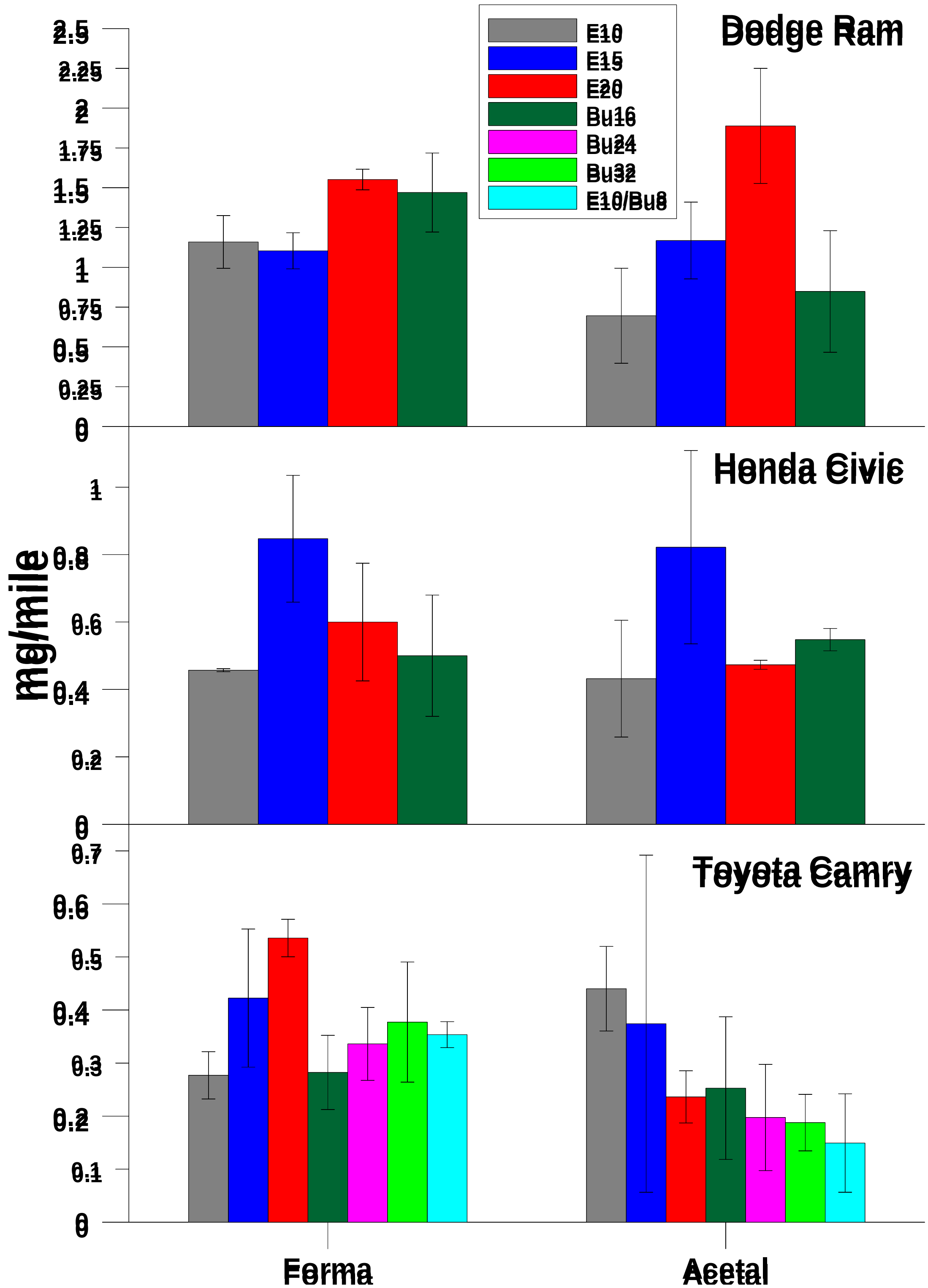
Generally, aldehydes and ketones form as a result of partial oxidation of the fuel components during combustion, as gasoline fuels do not contain carbonyl compounds. Previous studies have shown that the addition of ethanol and butanol fuels can produce higher formaldehyde and acetaldehyde emissions (Karavalakis et al., 2012; Graham et al., 2008; Yanowitz et al., 2013; Wallner and Frazee, 2010; Schifter et al., 2011). Formaldehyde is produced from oxygenated fuels and also by the decrease of fuel aromatics, since aromatics do not participate in the formation of formaldehyde (Zervas et al., 2002). For iso-butanol, formaldehyde is produced through the oxidation of methyl radicals to form CH3O and hydroxyl radicals that in turn yield formaldehyde. Formaldehyde is also formed by β-scission decomposition of the C_4H_8OH radical (Broustail et al., 2012; Sarathy et al., 2012). Acetaldehyde is principally produced through the partial oxidation of ethanol (Poulopoulos et al., 2001). Iso-butanol can also form acetaldehyde through the C-C bond scission reaction of iso-butanol and hydrogen atom abstraction from iso-butanol by hydrogen atom to produce C_4H_8OH radical, which further undergoes β-scission (Yasunaga et al., 2012). This formation pathway is not as strong as that for ethanol, however. McEnally and Pfefferle (2005) showed that branched butanols, through their fission produce hydroxyl-ethyl radicals, likely dissociate by β-scission of the O-H bond to produce acetaldehyde. Grana et al. (Grana et al., 2010) showed that the mole fraction of acetaldehyde is lower in the iso-butanol flame, which implies that there is a pathway for butanol fuels that destroys acetaldehyde and then creates formaldehyde. This is consistent with some of the trends seen in this study for the SIDI vehicles.

Butyraldehyde emissions appeared to be higher with the use of higher iso-butanol blends. This finding is in agreement with a recent chassis dynamometer study, which showed higher butyraldehyde emissions for butanol fuels (Ratcliff et al., 2013). Statistical analyses showed that butyraldehyde emissions were different between fuels for the FTP or the UC test cycles for both the conventional non-FFVs and the FFVs. For the non-FFVs, butyraldehyde emissions for Bu16 and B32 showed statistically significant increases of 672 percent (p=0.0167) and 817 percent (p=0.0052), respectively, compared to E20. For the FFVs, butyraldehyde emissions for Bu55 showed statistically significant increases of 261 percent (p=0.0039), 626 percent (p=<0.0001), and 269 percent (p=0.0034), respectively, compared to E10, E51, and E83 blends. It was assumed that butyraldehyde was formed via sequential H-atoms abstractions from the iso-butanol hydroxyl moiety to form a C_4H_9O radical, which then undergoes β-scission to yield butyraldehyde (Moss et al., 2008). The increased butyraldehyde emissions for the higher butanol blends could be an important finding because butyraldehyde has reactivity and mutagenicity properties that are similar to those of acetaldehyde (NIOSH). For the FFVs, higher propionaldehyde emissions for Bu55 relative to the ethanol blends were also observed, which can be attributed its formation from 1-propenol via H and/or HO_2 assisted enol-keto isomerization (Sarathy et al., 2012).

Benzaldehyde, which is primarily produced from fuel aromatic hydrocarbons, showed mixed trends with the alcohol fuels for the SIDI vehicles. Our results are in agreement with those studies showing that the addition of oxygenates generally decreases benzaldehyde emissions (Karavalakis et al., 2012; Storey et al., 2010; Broustail et al., 2012), but are also consistent with other studies showing some increases in benzaldehyde emissions probably because of the enhancement of aromatics oxidation (Zervas et al., 2002; Elghawi and Mayouf, 2014). We hypothesize that benzaldehyde can be produced from oxygen addition to alkyl branches of toluene, xylene, and trimethylbenzene present in gasoline.

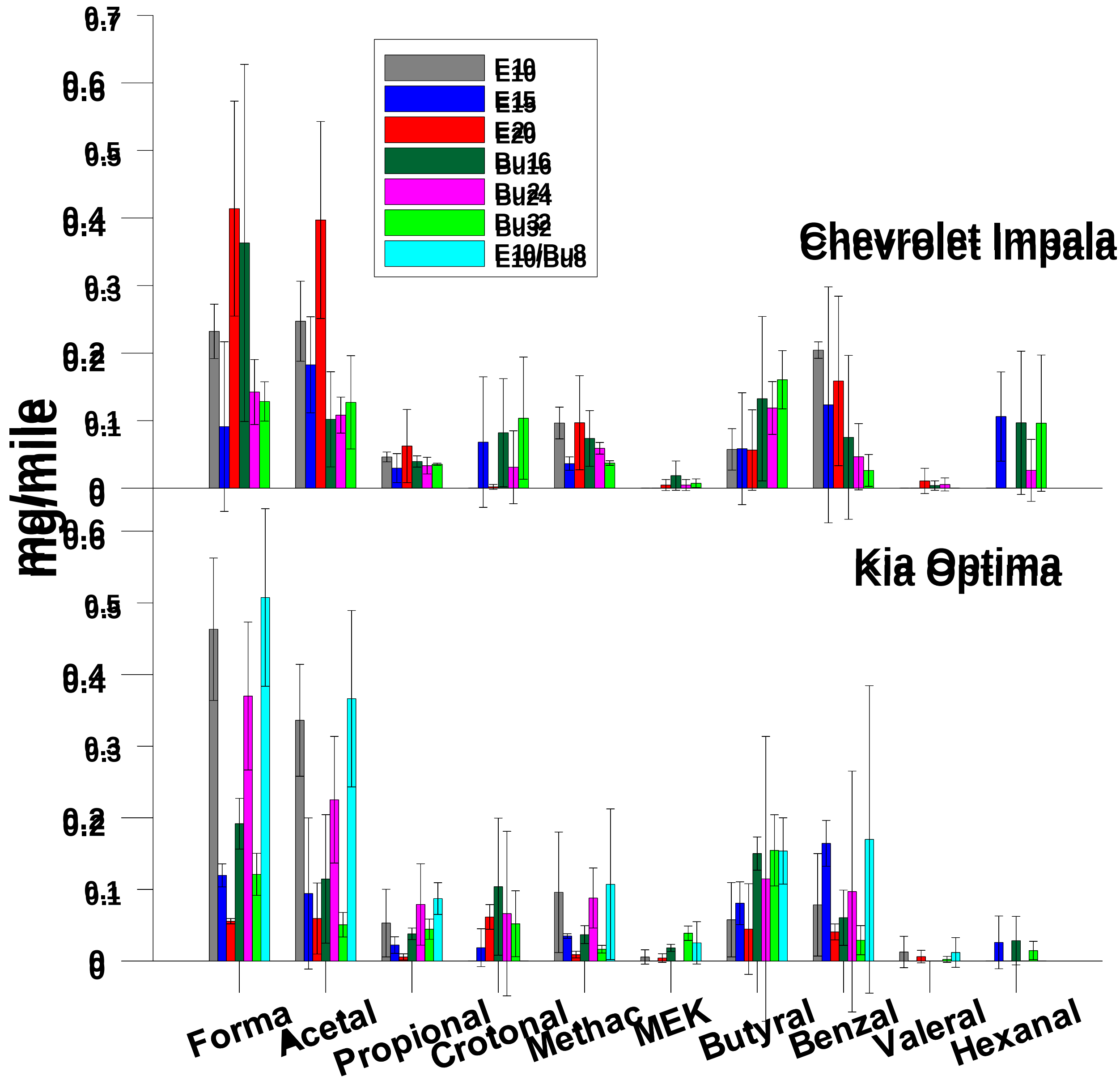
Carbonyl emissions were also influenced by the driving cycle and the cold-start phase of the FTP. In general, carbonyls were found to be higher during the cold-start phase and slightly higher during the hot-running phase of the FTP compared to phase 3. The fuel average total carbonyls were 3.45, 0.65, and 0.33 mg/mile for the Honda Civic, 8.13, 1.03, and 0.81 mg/mile for the Dodge Ram, and 1.37, 0.46, and 0.33 mg/mile for the Toyota Camry for the cold-start, hot-running, and hot-start phases of the FTP, respectively. For the SIDI vehicles, the fuel average total carbonyls were 2.34, 1.00, and 0.62 mg/mile for the Kia Optima, 2.05, 0.88, and 0.84 mg/mile for the Chevrolet Impala, 2.58, 0.98, and 1.04 mg/mile for the Mercedes Benz, and 2.19, 1.33, and 1.25 mg/mile for the Mazda3 for the cold-start, hot-running, and hot-start phases of the FTP, respectively. These observations indicate that the higher cold-start emissions are mainly related to catalyst inactivity, while the lower total carbonyls for phases 2 and 3 were due to the increased exhaust temperatures and the higher efficiency of the TWC, which facilitates the oxidation of aldehyde species.

Figure 40: Carbonyl Emissions for the PFI-fueled Passenger Cars Over the FTP



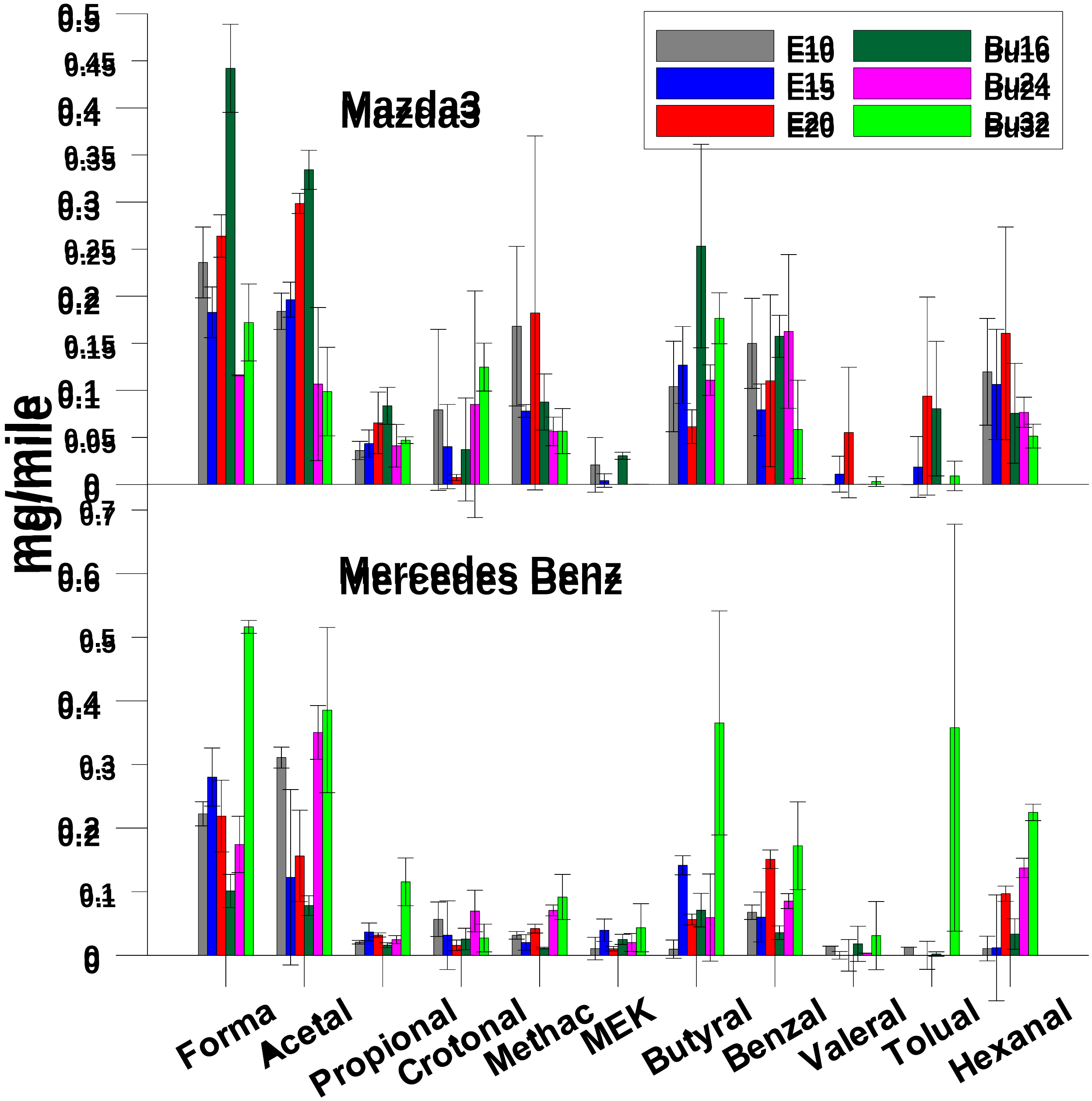
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 41: Carbonyl Emissions for Two SIDI-fueled Passenger Cars Over the FTP



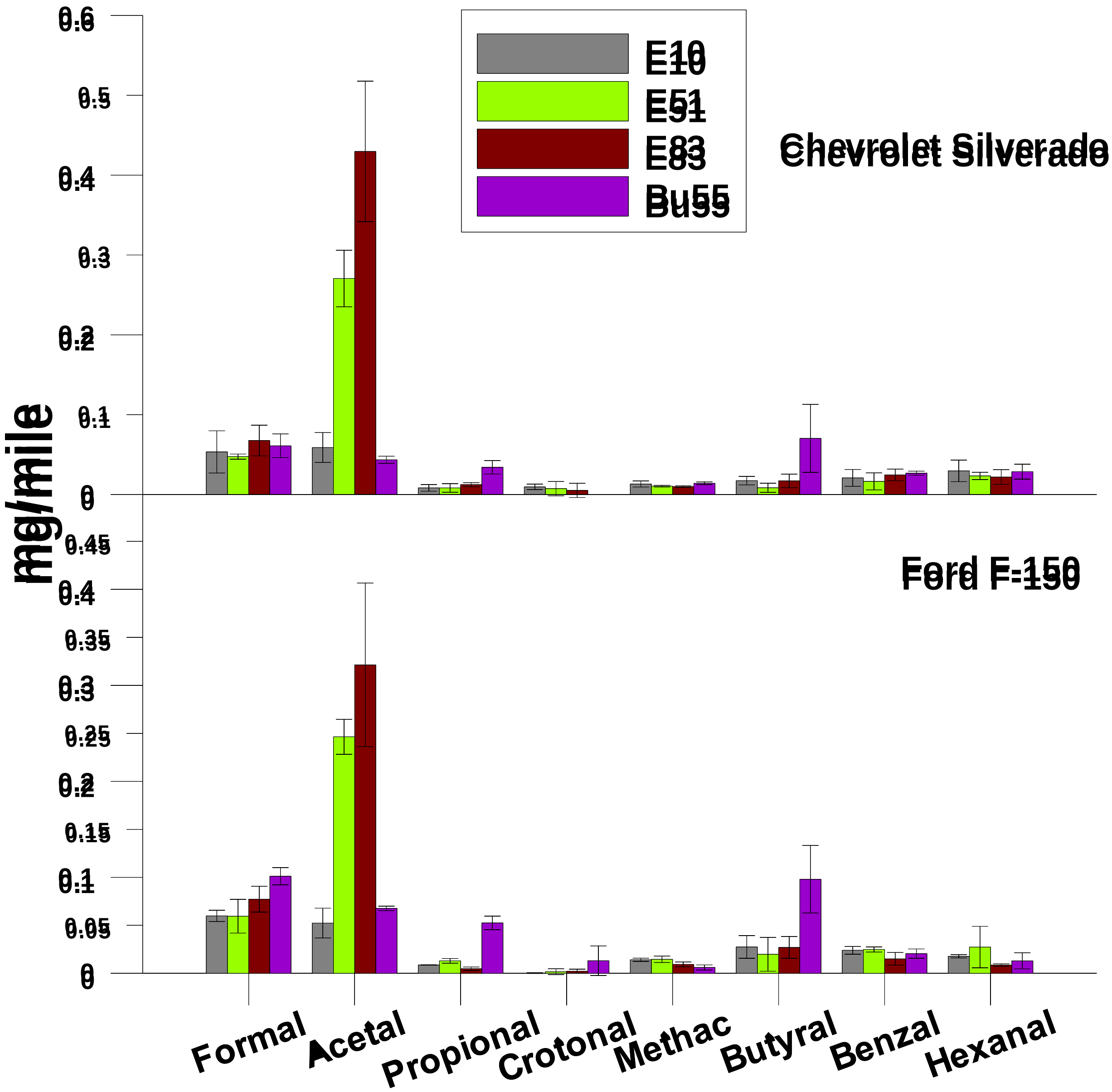
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 42: Carbonyl Emissions for Two SIDI-fueled Passenger Cars Over the FTP



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 43: Carbonyl Emissions for the FFV Vehicles Cars Over the FTP



Errors bars represent ± one standard deviation around the average value for each fuel.

3.8 1,3 Butadiene and BTEX Emissions

Figure 44 through Figure 50 present the cumulative 1,3-butadiene, benzene, ethylbenzene, toluene, m/p-xylene, and o-xylene for the PFI vehicles, SIDI vehicles, and FFVs, respectively, over the FTP test cycle. These pollutants were only measured for the FTP cycle. The monoaromatic hydrocarbons of benzene, ethylbenzene, toluene, *m*/*p*-xylene, and *o*-xylene are commonly termed BTEX. The most reactive volatile organic compounds (VOCs) from internal combustion engines are BTEX compounds, since they contain a C=C bond, that can add free radicals. It is evident that toluene was the most abundant VOC, followed by *m*/*p*-xylene and benzene.

For benzene emissions, whose principal source is partial combustion of toluene and xylene, there were no statistical significant differences between the fuels for the non-FFVs, although some specific vehicles/fuel combinations did show fuel differences. More specifically the Honda Civic and Mercedes Benz showed lower benzene emissions with the higher ethanol blends compared to E10. The Kia Optima and Chevrolet Silverado showed some increases in benzene emissions with some higher alcohol blends relative to E10. For the FFVs, the fuel effect on benzene emissions was particularly clear with E83 showing statistically significant reductions of 60 percent (p=0.0048) and 54 percent (p=0.0254), respectively, compared to E10 and E51.

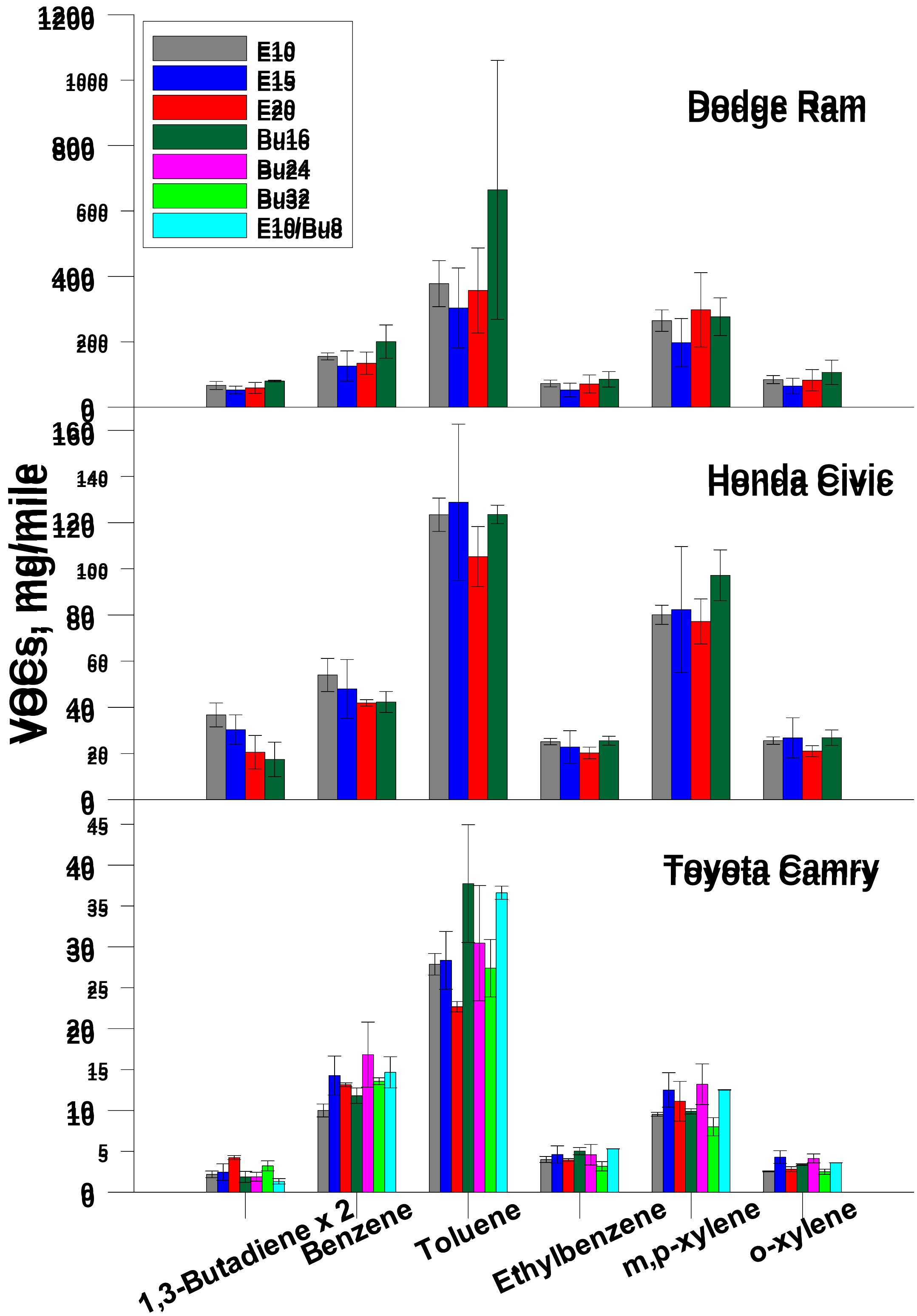
Toluene emissions did not show any strong fuel effects for the conventional PFI and SIDI vehicles. Some trends of higher toluene emissions were seen for the Kia Optima with increasing ethanol concentration in gasoline. On the other hand, the FFVs showed statistically significant differences in toluene emissions between the fuel blends. Toluene emissions showed statistically significant reductions of 66 percent (p=0.0049) and 88 percent (p=<0.0001), respectively, for E83 and Bu55 compared to E10. Statistically significant reductions in toluene emissions were also seen for E83 (61 percent, p=0.0229) and Bu55 (86 percent, p=<0.0001) compared to E51, and Bu55 (65 percent, p=0.0064) compared to E83.

Ethylbenzene emissions did not exhibit any significant differences between fuels for the non-FFVs with the exception of Bu32, which showed a 39 percent (p=0.0293) reduction compared to Bu16 at a statistically significant level. For the FFVs, ethylbenzene emissions showed reductions with the use of higher alcohol blends, with most of these differences being statistically significant. The blends of E83 and Bu55 showed statistically significant reductions on the order of 79 percent (p=<0.0001) and 77 percent (p=0.0001), respectively, relative to E10, whereas E83 and Bu55 showed statistically significant reductions on the order of 84 percent (p=<0.0001) and 82 percent (p=<0.0001), respectively, compared to E51.

Emissions of *m*/*p*-xylene resulted in some statistical significant differences for some fuels for the non-FFVs. It might be expected that the emissions of *m*/*p*-xylenes would decrease with the addition of higher ethanol and iso-butanol blends due to their lower monoaromatics content. Statistically significant reductions in *m*/*p*-xylene emissions for Bu32 of 41 percent (p=0.0005), 33 percent (p=0.0193), and 39 percent (p=0.0024), respectively, were seen compared to the E20, Bu16, and Bu24 blends. On the other hand, a marginally statistically significant increase of 35 percent (p=0.0958) was seen for E20 for in *m*/*p*-xylene emissions compared to E10. For *o*-xylene emissions for the non-FFVs, Bu32 showed statistically significant reductions of 32 percent (p=0.0421), 35percent (p=0.0086), 42 percent (p=0.0005), and 38 percent (p=0.0040), respectively, compared to E15, E20, Bu16, and Bu24 blends. Similar to the conventional PFI and SIDI vehicles, the FFVs showed decreases in *m*/*p*-xylene emissions with the use of higher alcohol blends. Specifically, E83 and Bu55 showed statistically significant reductions in m/p-xylene emissions on the order of 84 percent (p=<0.0001) and 74 percent (p=0.0003), respectively, compared to E10 and of 72 percent (p=0.0004) and 54 percent (p=0.0272), respectively, compared to E51. A similar picture was also observed for o-xylene emissions with E83 and Bu55 showing statistically significant reductions of 77 percent (p=<0.0001) and 75 percent (p=0.0002), respectively, compared to E10, and 66 percent (p=0.0015) and 64 percent (p=0.0026), respectively, compared to E51.

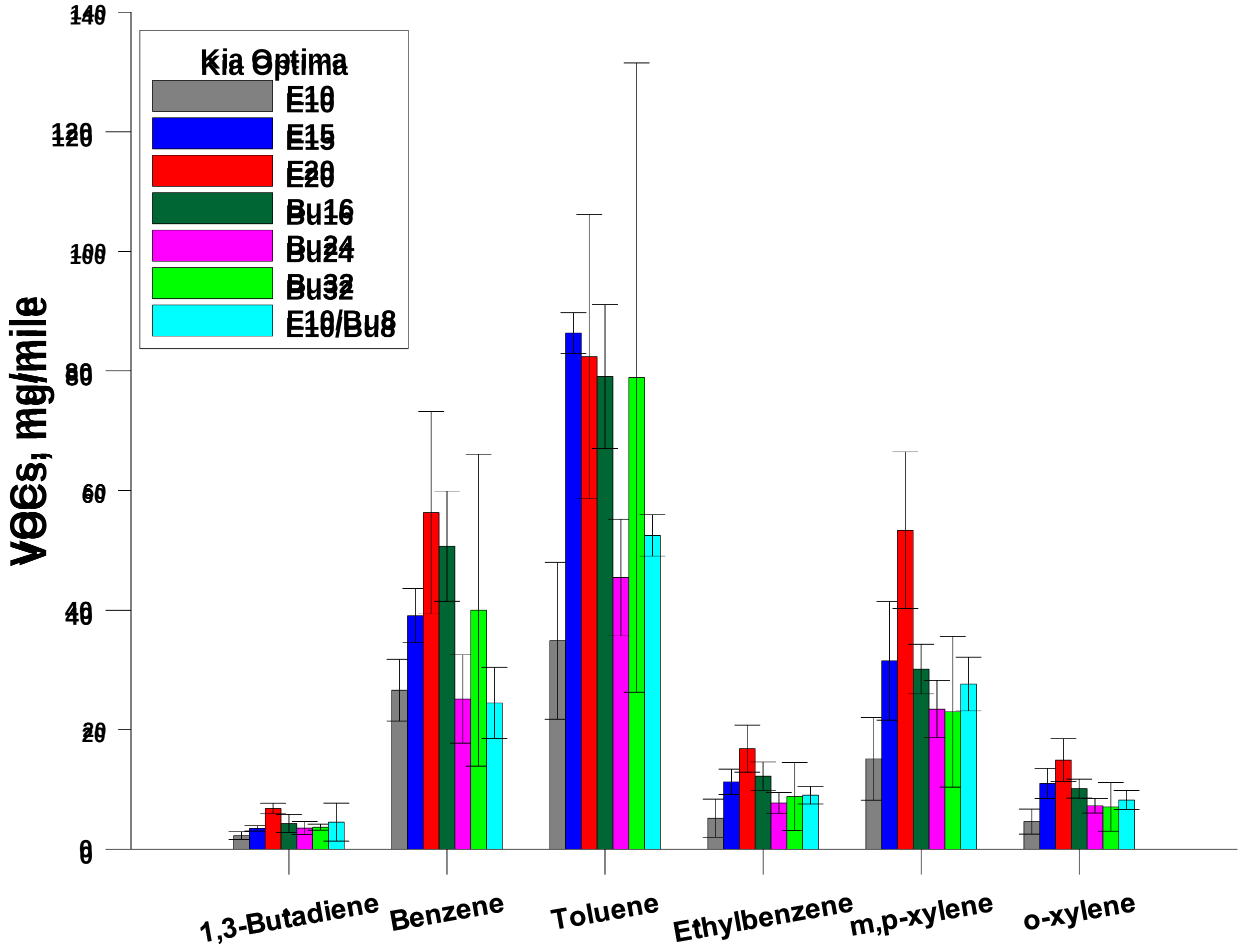
Emissions of 1,3-butadiene, which is a classified carcinogenic compound to humans, were generally found at very low concentrations for all vehicle/fuel combinations compared to the monoaromatic VOCs. Although 1,3-butadiene did not show any statistical significant differences between fuels for the non-FFVs, some increases were seen for the butanol blends compared to the ethanol blends. For the FFVs, this trend was more pronounced, with the Bu55 blend showing a statistically significant increase of 318 percent (p=0.0162) compared to E83. For iso-butanol, 1,3-butadiene can be formed from reactions with propargyl or vinyl radicals with ethane, or from the decomposition of the fuel itself.

Figure 44: VOC Emissions for the PFI-fueled Passenger Cars Over the FTP



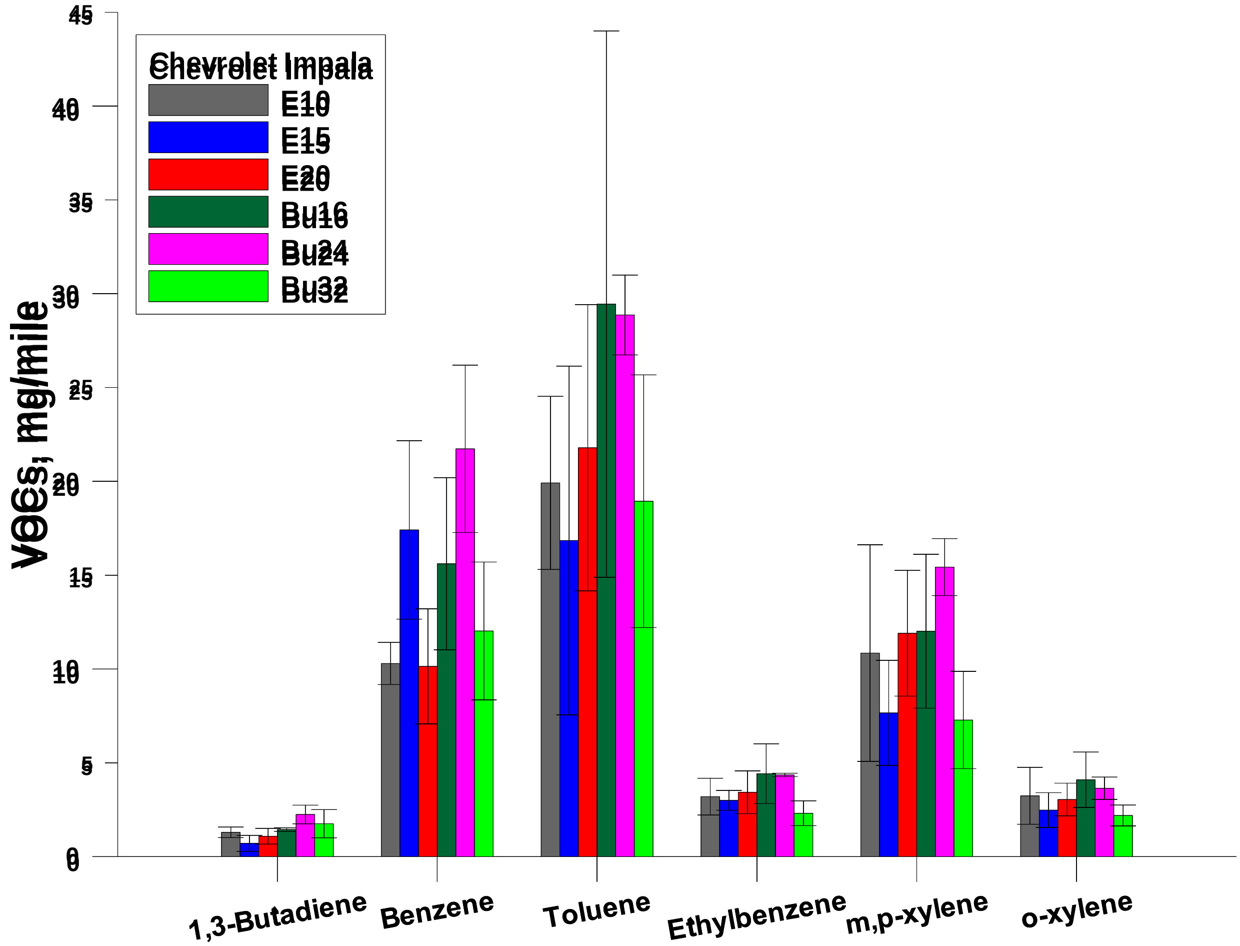
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 45: VOC Emissions for the Kia Optima Over the FTP



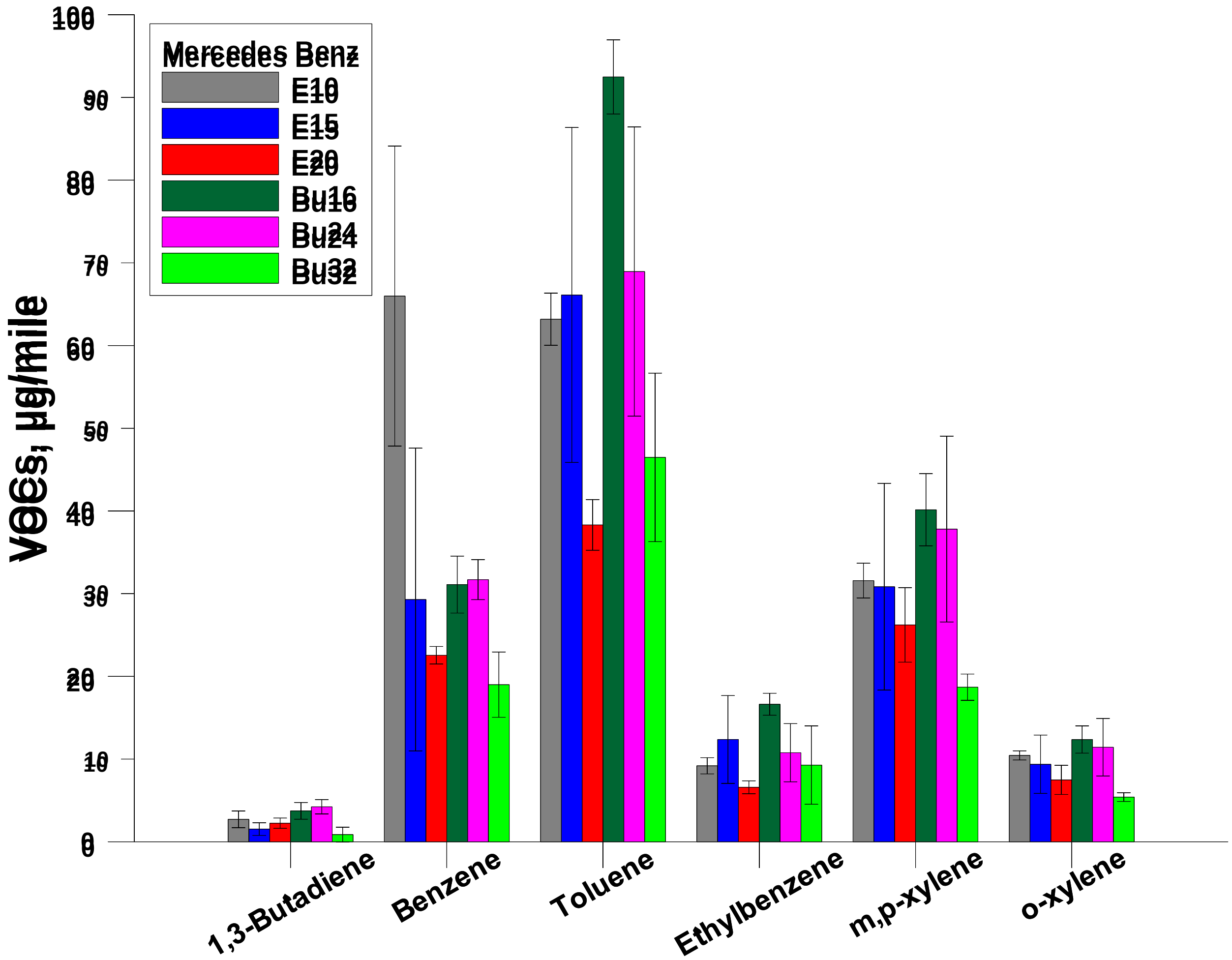
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 46: VOC Emissions for the Chevrolet Over the FTP



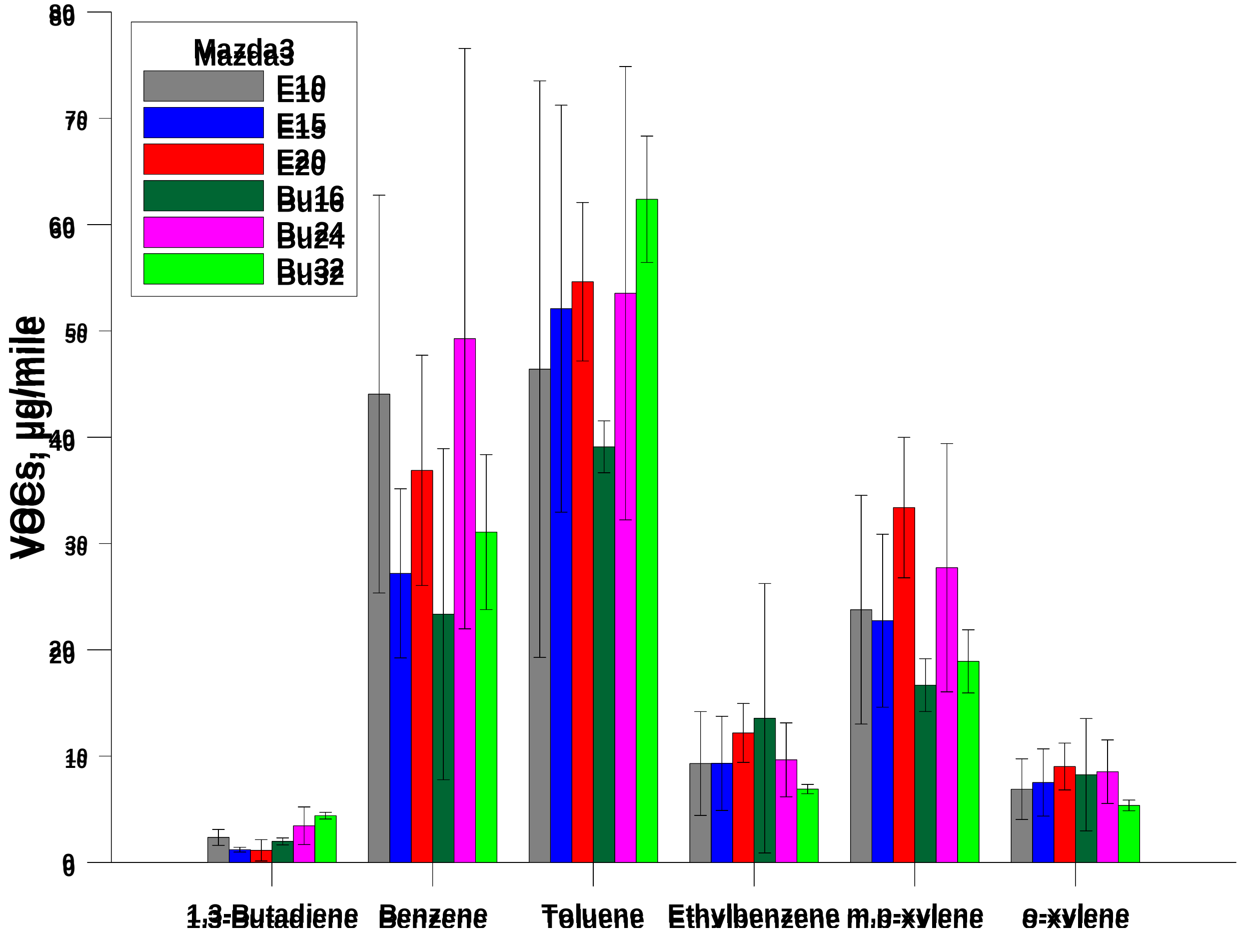
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 47: VOC Emissions for the Mercedes Benz Over the FTP



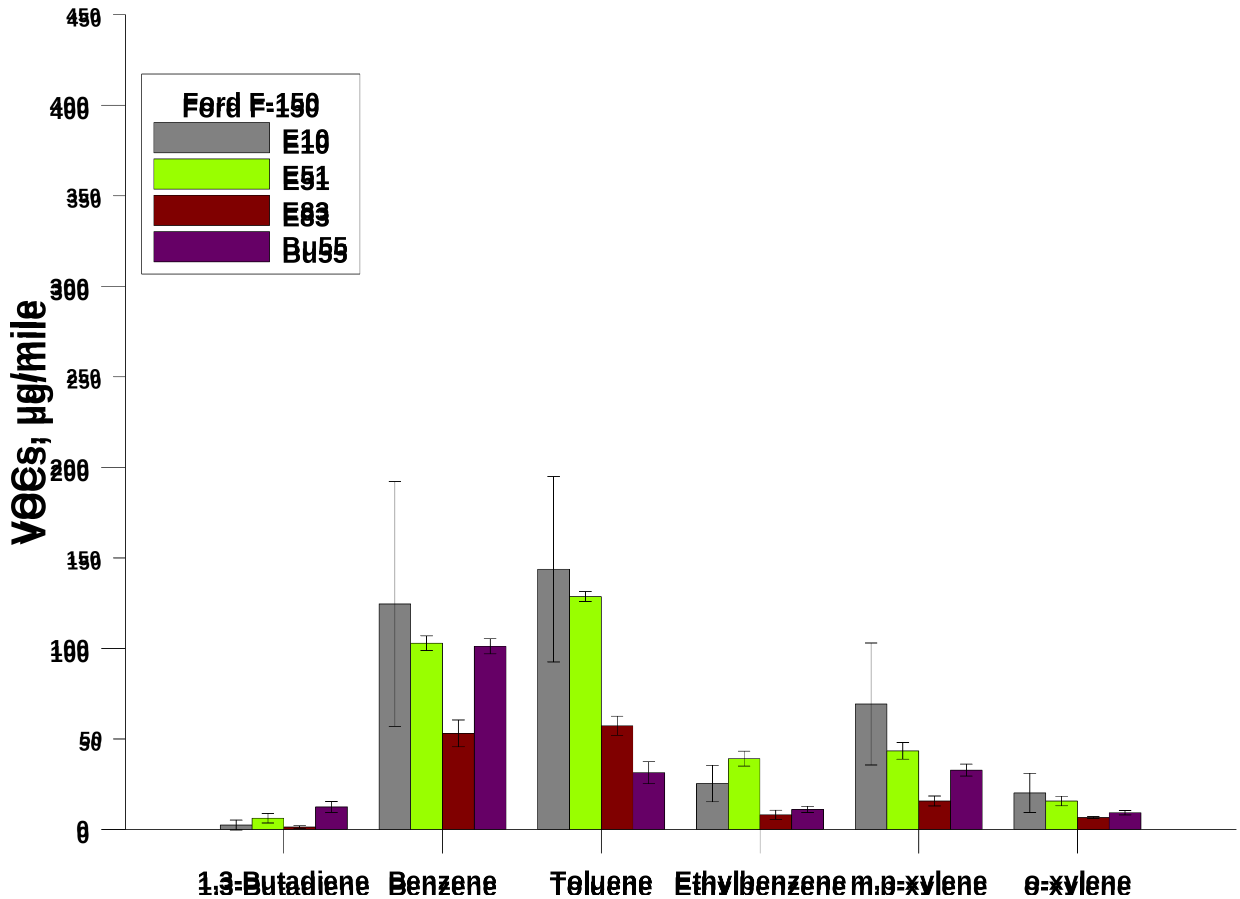
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 48: VOC Emissions for the Mazda3 Over the FTP



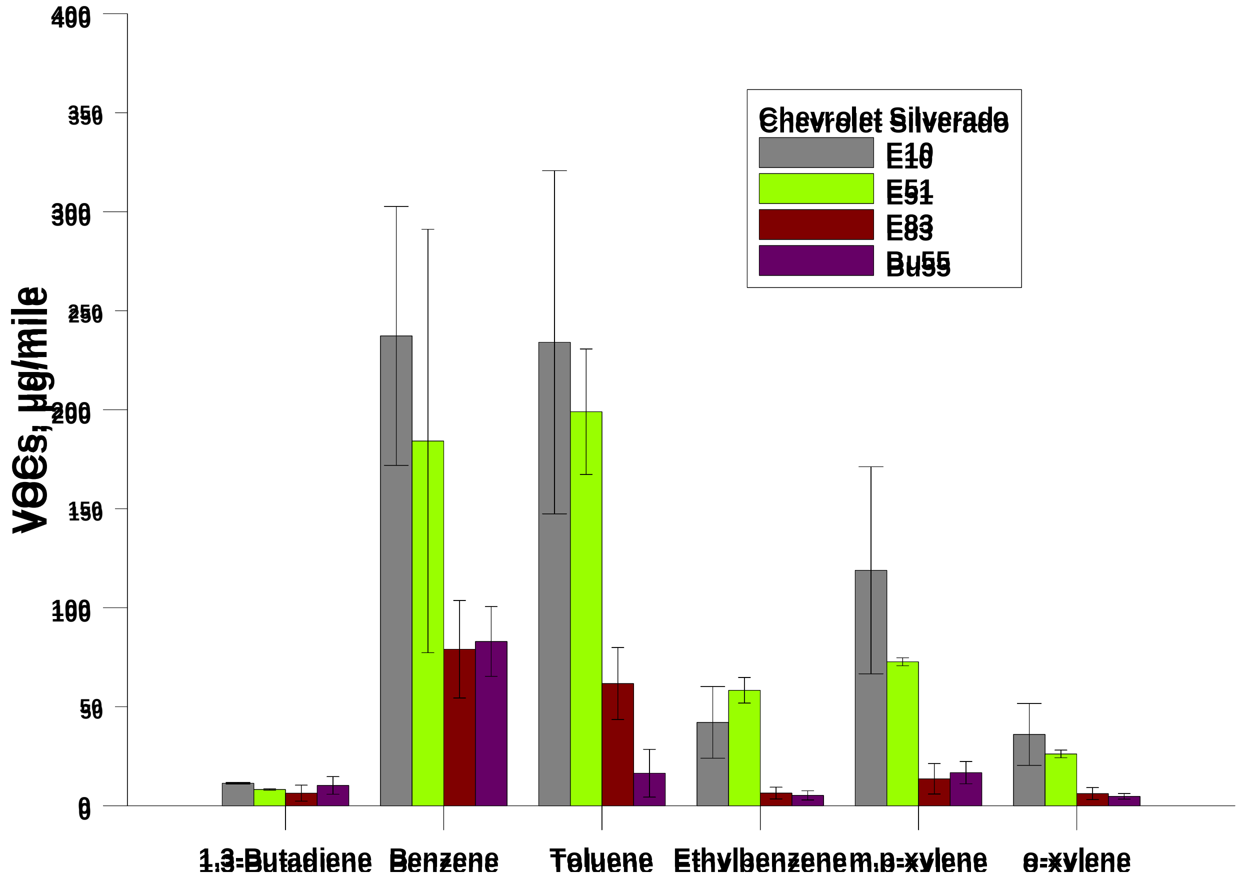
Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 49: VOC Emissions for the FFV Ford F-150 Over the FTP



Errors bars represent ± one standard deviation around the average value for each fuel.

Figure 50: VOC Emissions for the FFV Chevrolet Silverado Over the FTP



Errors bars represent ± one standard deviation around the average value for each fuel.

CHAPTER 4: Summary and Conclusions

This study evaluated the potential emissions impacts of different alcohol blends on a fleet of modern gasoline vehicles. Testing was conducted on a fleet of 9 vehicles over different combinations of 10 fuel blends. A total of 48 different vehicle/fuel combinations were included in the test matrix. The vehicles ranged in model year from 2007-2014 and included 4 SIDI vehicles and 2 FFVs. The 10 fuel blends included E10, E15, E20, Bu16, Bu24, Bu32, an E10/Bu8 blend, and E51, Bu55, and E83 fuels for FFVs. At each test matrix point, the vehicles were run over 3 Federal Test Procedure (FTP) cycles and 3 Unified Cycles. Emissions measurements were made for the typical regulated emissions on each test, including THC, NMHC, NOx, CO, CO2, and fuel economy. More detailed measurements of the hydrocarbon species were also made, including BTEX [benzene, toluene, ethyl-benzene, and xylene] compounds, 1,3-butadiene, and carbonyls. Additional measurements of PM mass, particle number emissions, particle size distributions, and black carbon were also made.

A summary of the findings and conclusions of this study are as follows:

- Fuel effects showed mixed results for different vehicles and cycles for THC, NMHC, and NO_x emissions and did not show any statistically significant differences for the weighted emissions for these pollutants. Cold-start THC and NMHC emissions were lower for the E10/Bu8 blend compared to most of the other blends for the non-FFVs.

- CH_4 weighted emissions for the FFVs were higher for the higher alcohol blends (E51, Bu55, and E83) compared to E10, and were higher for E83 compared to the E51 and Bu55 mid-level blends.

- There were some trends toward lower CO emissions with the higher alcohol fuel blends. For the FFVs, weighted and cold-start CO emissions were lower for E83 than the E10, E51, and Bu55 fuels. This is consistent with previous studies that have shown reductions in CO with increasing alcohol content due to improved oxidation of the CO as a result of the oxygen content in the fuel.

- CO_2 emissions showed some differences between different fuels, but not over all testing conditions. From a theoretical standpoint, it might be expected that CO_2 emissions would trend with the carbon/hydrogen ratio in the fuel, with lower CO_2 emissions for the higher alcohol blends with lower carbon/hydrogen ratios. This trend was seen for some fuel/cycle combinations, but not for others. The main effects were that E20 had lower CO_2 emissions than other fuels for the non-FFVs, and that the E83 fuel had lower emissions than the other fuels for the FFVs.

- Fuel economy decreased as the alcohol concentration increased, at a level that was approximately proportionally to the decrease in energy content of the blend. This trend was consistent for both non-FFVs and FFVs, with the E20, Bu32, and E83 blends showing the lowest fuel economies, although lower fuel economy for the E20 and Bu32 fuels was not found for all cycle phases. The Bu55 fuel also showed a higher fuel economy than the E51 fuel.

- PM mass and total particle number emissions were higher for the SIDI vehicles, with the exception of the PFI Ford F-150. Overall, cumulative PM emission results showed reductions with higher oxygen levels for the FFVs over the UC, while E20 showed lower PM emissions than the Bu16 and Bu24 fuels for the non-FFVs. For most vehicles, particle number emissions corroborate the PM mass trends, with the exception of the PFI Ford F-150. Weighted particle number emissions showed lower emissions for the E20 and Bu32 fuels for the non-FFVs, and lower emissions for the higher alcohol blends for the FFVS with E83 showing the lowest emissions.

- Overall, the black carbon results were mixed and did not follow a uniform trend for both test cycles, although there were trends of lower black carbon emissions with increasing alcohol content for different vehicle/cycle combinations. Black carbon emissions were 3 to 7 times higher for the SIDI vehicles compared to PFI vehicles, suggesting that SIDI PM were primarily elemental carbon or soot in nature. A relatively good correlation was found for black carbon and particle number emissions for the PFI vehicles, especially for the FTP, although the correlation was not strong for the UC or the SIDI vehicles.

- In general, the SIDI vehicles displayed diesel-like distributions that were unimodal in nature. The size distributions for the FFVs showed emissions of nucleation mode particles in the size range of 10-30 nm for most fuels, with the exception of E10 that showed a decidedly bimodal particle size distribution with nucleation mode particles peaking at 11 nm and a higher peak for accumulation particles. The peak number concentrations for the wall-guided SIDI vehicles were substantially higher than those of the spray-guided SIDI vehicle, with the Kia Optima having the highest concentration of accumulation mode particles followed by the Chevrolet Impala, and Mazda3. The particle size distributions showed reduced particle number concentrations with higher oxygen content blends. The majority of vehicles showed marked reductions in accumulation mode particles with E20 and Bu32 blends, while Bu32 generally shifted towards smaller particle diameters than E20. For the FFVs, the higher oxygen/lower aromatic content E51, E83, and Bu55 systematically showed lower number concentrations of accumulation mode particles, and a smaller size in geometric mean diameter compared to E10.

- Lower molecular-weight aldehydes such as formaldehyde and acetaldehyde were the most abundant carbonyl compounds in the tailpipe for all vehicle/fuel combinations. Total carbonyl emissions for E20 and Bu16 were higher than those of E10. For the non-FFVs, the fuel blends did not show any statistically significant effect on formaldehyde and acetaldehyde emissions. For the FFVs, acetaldehyde emissions increased significantly for the E51 and E83 fuels. For butyraldehyde, increases were found for Bu16 and Bu32 compared to E20 for the non-FFVs, and for Bu55 compared to the E10, E51, and E83 blends for the FFVs.

- Toluene was the most abundant BTEX VOC, followed by *m*/*p*-xylene and benzene. For the non-FFVs, benzene and toluene did not show any statistically significant fuel effects, while the Bu32 fuel showed statistically significant reductions in ethylbenzene, *m*/*p*-xylene, and *o*-xylene relative to different combinations of fuels. For the FFVs, E83 and Bu55 showed lower emissions for the various BTEX species compared to E10 and E51. Emissions of 1,3-butadiene were found at very low concentrations compared to the monoaromatic VOCs. For the FFVs, the Bu55 blend showed a statistically significant increase in 1,3-butadiene compared to E83.

GLOSSARY

Term	Definition
ABE	Acetone-butanol-ethanol
ARB	Air Resources Board
BTEX	Benzene, toluene, ethyl-benzene, and xylene
CE-CERT	College of Engineering-Center for Environmental Research and Technology (University of California, Riverside)
CFR	Code of Federal Regulations
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
CPC	Condensation particle counter
DI	Direct injection
DNPH	2,4-dinitrophenylhydrazine
EPA	Environmental Protection Agency
EEPS	Engine Exhaust Particle Sizer
EU	European Union
FTP	Federal Test Procedure
FFV	Flexible fuel vehicle
g/mi	Grams per mile
HPLC	High performance liquid chromatograph
LDV	Light-duty vehicle
LNT	Lean NOx traps
MAAP	Multi-angle absorption photometer
N2	Nitrogen
NEDC	New European Driving Cycle
NMHC	Non-methane hydrocarbons

NMOG	Non-methane organic gases
NOx	Oxides of nitrogen
OEM	Original equipment manufacturer
PAHs	Polycyclic aromatic hydrocarbons
PDP-CVS	Positive Displacement Pump-Constant Volume Sampling
PFI	Port fuel injection
PM	Particulate matter
RVP	Reid vapor pressure
RFS	Renewable Fuel Standard
THC	Total hydrocarbons
TWC	Three-way catalysts
SG	Spray-guided
SI	Spark-ignition
SIDI	Direct injection spark ignition
SULEV	Super ultra-low emission vehicle
UC	Unified Cycle
UDDS	Urban Dynamometer Driving Schedule
UFP	Ultrafine particle
ULEV	Ultra low emission vehicle
U.S	United States
VERL	Vehicle Emissions Research Laboratory
WG-SIDI	Wall-guided direct

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APPENDIX A:
Emissions Test Results

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2007 Honda Civic	FTP1	E10	5/30/2012	0.107	0.006	0.005	0.027	0.098	0.005	0.002	0.024	0.011	0.001	0.003	0.004	0.628	0.257	0.152	0.305	0.042	0.000	0.002	0.009	288	282	237	271	29.6	30.2	36.1	31.5
2007 Honda Civic	FTP2	E10	5/31/2012	0.108	0.012	0.016	0.033	0.099	0.011	0.014	0.030	0.010	0.001	0.003	0.003	0.529	0.230	0.229	0.292	0.042	0.001	0.003	0.010	280	275	237	266	30.4	31.0	36.0	32.1
2007 Honda Civic	FTP3	E10	6/1/2012	0.113	0.013	0.015	0.034	0.105	0.012	0.013	0.032	0.009	0.001	0.003	0.003	0.442	0.224	0.169	0.254	0.044	0.000	0.002	0.010	279	269	230	261	30.5	31.7	37.0	32.7
2007 Honda Civic	FTP1	E15	5/15/2012	0.098	0.008	0.006	0.026	0.089	0.007	0.003	0.023	0.010	0.001	0.003	0.003	0.470	0.183	0.193	0.246	0.038	0.001	0.004	0.010	280	279	237	268	29.8	29.9	35.2	31.2
2007 Honda Civic	FTP2	E15	5/16/2012	0.129	0.002	0.005	0.029	0.120	0.001	0.002	0.026	0.011	0.001	0.004	0.004	0.522	0.178	0.170	0.248	0.039	0.001	0.004	0.010	288	289	240	275	28.9	28.9	34.8	30.3
2007 Honda Civic	FTP3	E15	5/17/2012	0.140	0.002	0.003	0.031	0.131	0.002	0.001	0.028	0.010	0.001	0.003	0.003	0.492	0.228	0.150	0.261	0.071	0.001	0.004	0.016	285	289	240	275	29.2	28.9	34.8	30.3
2007 Honda Civic	FTP1	E20	6/5/2012	0.112	0.007	0.004	0.028	0.104	0.006	0.001	0.025	0.010	0.002	0.003	0.004	0.453	0.206	0.124	0.235	0.054	0.001	0.011	0.015	279	284	240	271	29.2	28.8	34.1	29.2
2007 Honda Civic	FTP2	E20	6/6/2012	0.107	0.002	0.004	0.024	0.098	0.001	0.001	0.021	0.010	0.001	0.003	0.003	0.426	0.138	0.185	0.211	0.049	0.001	0.006	0.012	287	283	238	272	28.4	28.8	34.3	28.4
2007 Honda Civic	FTP3	E20	6/8/2012	0.095	0.002	0.004	0.022	0.087	0.001	0.001	0.019	0.010	0.001	0.003	0.003	0.489	0.170	0.173	0.237	0.044	0.001	0.012	0.013	277	278	233	265	29.4	29.4	35.1	29.4
2007 Honda Civic	FTP1	iBut16	6/19/2012	0.109	0.002	0.004	0.025	0.100	0.001	0.001	0.022	0.010	0.001	0.003	0.003	0.522	0.204	0.129	0.250	0.040	0.001	0.013	0.013	282	286	234	271	30.5	30.2	36.9	31.9
2007 Honda Civic	FTP2	iBut16	6/20/2012	0.126	0.001	0.006	0.029	0.117	0.001	0.002	0.025	0.010	0.001	0.004	0.004	0.515	0.169	0.172	0.242	0.051	0.000	0.012	0.014	280	277	239	267	30.7	31.2	36.1	32.3
2007 Honda Civic	FTP3	iBut16	6/21/2012	0.105	0.002	0.004	0.024	0.096	0.001	0.001	0.021	0.010	0.001	0.003	0.004	0.451	0.220	0.170	0.255	0.042	0.001	0.009	0.012	277	277	232	264	31.0	31.2	37.3	32.6
2007 Honda Civic	UNI1	E10	5/24/2012	0.284	0.003	0.012	0.018	0.260	0.002	0.005	0.016	0.028	0.001	0.009	0.003	1.167	0.287	0.399	0.340	0.084	0.002	0.002	0.006	502	280	375	298	16.9	30.5	22.7	28.6
2007 Honda Civic	UNI2	E10	5/25/2012	0.310	0.003	0.011	0.019	0.285	0.002	0.005	0.017	0.028	0.001	0.008	0.003	1.175	0.249	0.329	0.303	0.068	0.002	0.005	0.006	489	275	363	292	17.4	31.1	23.5	29.2
2007 Honda Civic	UNI3	E10	5/27/2012	0.305	0.006	0.012	0.022	0.278	0.005	0.005	0.019	0.031	0.001	0.007	0.003	1.313	0.280	0.450	0.345	0.072	0.003	0.001	0.006	505	273	360	291	16.8	31.2	23.7	29.3
2007 Honda Civic	UNI1	E15	5/18/2012	0.255	0.004	0.010	0.017	0.231	0.003	0.003	0.014	0.028	0.001	0.009	0.003	0.819	0.260	0.313	0.292	0.073	0.005	0.027	0.010	499	275	365	292	16.7	30.4	22.8	28.5
2007 Honda Civic	UNI2	E15	5/22/2012	0.289	0.003	0.010	0.019	0.263	0.002	0.004	0.016	0.030	0.001	0.008	0.003	0.846	0.229	0.235	0.261	0.106	0.003	0.003	0.008	488	275	362	292	17.1	30.4	23.1	28.6
2007 Honda Civic	UNI3	E15	5/23/2012	0.272	0.003	0.011	0.018	0.245	0.002	0.003	0.015	0.031	0.001	0.009	0.003	1.017	0.226	0.270	0.271	0.079	0.006	0.004	0.010	496	276	383	295	16.8	30.2	21.8	28.3
2007 Honda Civic	UNI1	E20	6/12/2012	0.335	0.004	0.009	0.021	0.308	0.003	0.002	0.018	0.032	0.002	0.008	0.004	1.143	0.179	0.194	0.229	0.137	0.007	0.010	0.014	510	269	363	288	15.9	30.3	22.5	29.2
2007 Honda Civic	UNI3	E20	6/14/2012	0.281	0.003	0.009	0.018	0.256	0.002	0.002	0.015	0.029	0.001	0.008	0.003	1.107	0.195	0.301	0.249	0.090	0.003	0.005	0.007	504	269	359	287	16.2	30.3	22.8	28.4
2007 Honda Civic	UNI4	E20	6/15/2012	0.319	0.003	0.010	0.020	0.292	0.002	0.002	0.017	0.031	0.001	0.009	0.003	1.110	0.199	0.363	0.257	0.098	0.004	0.005	0.009	513	270	365	289	15.9	30.2	22.4	29.4
2007 Honda Civic	UNI1	iBut16	6/22/2012	0.329	0.003	0.009	0.020	0.305	0.002	0.001	0.018	0.028	0.001	0.008	0.003	0.970	0.233	0.241	0.271	0.118	0.003	0.005	0.009	484	264	363	282	17.8	32.7	23.8	30.6
2007 Honda Civic	UNI2	iBut16	6/26/2012	0.291	0.003	0.009	0.018	0.265	0.002	0.003	0.016	0.030	0.001	0.007	0.003	1.147	0.227	0.256	0.276	0.113	0.003	0.023	0.010	485	263	365	281	17.7	32.8	23.7	30.7
2007 Honda Civic	UNI3	iBut16	7/3/2012	0.300	0.003	0.012	0.019	0.275	0.003	0.005	0.017	0.029	0.001	0.008	0.003	1.299	0.271	0.343	0.328	0.085	0.003	0.002	0.007	503	268	360	287	17.1	32.1	24.0	30.1

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	PN #/mile				Black Carbon µg/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	PN-1	PN-2	PN-3	PN-w	BC-1	BC-2	BC-3	BC-w
2007 Honda Civic	FTP1	E10	5/30/2012	16.7	60.3	131.6	26.6	84.3	27.0	453.9	455.5	3.23E+11	9.27E+10	3.19E+10	1.24E+11	2.54E+02	1.64E+02	2.75E+01	1.45E+02
2007 Honda Civic	FTP2	E10	5/31/2012	21.4	55.6	118.1	23.9	76.1	23.8	460.3	248.3	2.14E+11	9.79E+10	4.33E+10	1.07E+11	9.66E+01	6.56E+01	2.87E+01	6.19E+01
2007 Honda Civic	FTP3	E10	6/1/2012	17.0	46.2	120.6	25.0	79.9	26.0	872.6	592.2	7.82E+10	2.27E+10	3.64E+10	3.79E+10	1.56E+02	2.36E+02	1.91E+01	1.60E+02
2007 Honda Civic	FTP1	E15	5/15/2012	12.5	39.3	89.9	14.7	51.3	16.8	629.9	507.0	3.94E+11	1.21E+11	5.02E+10	1.58E+11	2.92E+02	2.13E+02	4.77E+01	1.84E+02
2007 Honda Civic	FTP2	E15	5/16/2012	18.7	62.6	150.7	26.1	93.0	30.8	950.3	1068.1	NA	NA	NA	NA	2.40E+02	2.36E+02	3.49E+01	1.82E+02
2007 Honda Civic	FTP3	E15	5/17/2012	14.3	42.0	145.9	27.7	102.7	32.7	960.9	890.8	NA	NA	NA	NA	NA	NA	NA	NA
2007 Honda Civic	FTP1	E20	6/5/2012	12.9	40.9	114.5	22.0	84.1	22.7	476.5	463.7	4.07E+11	3.98E+10	NA	NA	2.15E+02	1.55E+02	2.08E+01	1.30E+02
2007 Honda Civic	FTP2	E20	6/6/2012	NA	NA	NA	NA	NA	NA	257.3	260.4	2.70E+11	8.31E+10	3.57E+10	1.09E+11	1.92E+02	1.72E+02	3.93E+01	1.40E+02
2007 Honda Civic	FTP3	E20	6/8/2012	7.7	42.9	96.1	18.5	70.3	19.4	723.4	482.6	NA	NA	NA	NA	NA	NA	NA	NA
2007 Honda Civic	FTP1	iBut16	6/19/2012	11.7	46.9	123.1	24.3	90.0	24.6	350.4	215.9	3.84E+11	6.17E+10	9.46E+10	1.38E+11	1.73E+02	2.05E+02	2.55E+01	1.49E+02
2007 Honda Civic	FTP2	iBut16	6/20/2012	10.0	37.8	119.8	27.8	109.9	30.7	373.0	571.3	3.09E+11	1.57E+11	1.15E+11	1.77E+11	2.08E+02	1.02E+02	4.04E+01	1.07E+02
2007 Honda Civic	FTP3	iBut16	6/21/2012	4.5	42.3	127.8	24.5	91.7	25.3	627.4	524.5	4.48E+11	1.12E+11	6.20E+10	1.68E+11	1.81E+02	2.17E+02	2.96E+01	1.58E+02
2007 Honda Civic	UNI1	E10	5/24/2012									1.13E+12	2.05E+11	1.57E+10	2.40E+11	2.10E+02	8.31E+01	2.43E+01	8.57E+01
2007 Honda Civic	UNI2	E10	5/25/2012									7.42E+11	7.90E+10	3.15E+11	1.30E+11	3.98E+02	9.53E+01	6.49E+01	1.09E+02
2007 Honda Civic	UNI3	E10	5/27/2012									9.39E+11	8.73E+10	9.04E+10	1.32E+11	2.10E+02	1.44E+02	4.89E+01	1.41E+02
2007 Honda Civic	UNI1	E15	5/18/2012									1.56E+12	1.95E+11	7.30E+10	2.57E+11	3.16E+02	1.12E+02	1.75E+01	1.16E+02
2007 Honda Civic	UNI2	E15	5/22/2012									1.55E+12	NA	NA	NA	1.62E+02	6.50E+01	2.90E+01	6.75E+01
2007 Honda Civic	UNI3	E15	5/23/2012									1.19E+12	1.36E+11	4.98E+10	1.85E+11	4.46E+02	1.63E+02	2.15E+01	1.68E+02
2007 Honda Civic	UNI1	E20	6/12/2012									1.42E+12	NA	6.62E+10	NA	2.89E+02	1.00E+02	1.70E+01	1.04E+02
2007 Honda Civic	UNI3	E20	6/14/2012									5.18E+11	1.52E+11	NA	NA	3.52E+02	1.30E+02	NA	NA
2007 Honda Civic	UNI4	E20	6/15/2012									2.29E+11	2.54E+11	6.88E+10	2.40E+11	2.44E+02	8.38E+01	2.63E+01	8.81E+01
2007 Honda Civic	UNI1	iBut16	6/22/2012									2.80E+11	9.52E+10	9.99E+10	1.05E+11	2.96E+02	8.07E+01	3.26E+01	8.84E+01
2007 Honda Civic	UNI2	iBut16	6/26/2012									8.25E+11	5.02E+11	6.63E+10	4.89E+11	4.58E+02	9.45E+01	2.33E+01	1.08E+02
2007 Honda Civic	UNI3	iBut16	7/3/2012									1.10E+12	6.37E+10	2.55E+10	1.14E+11	2.26E+02	9.26E+01	1.88E+01	9.44E+01

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2007 Dodge Ram	FTP1	E10	5/15/2012	0.465	0.013	0.043	0.116	0.421	0.008	0.023	0.098	0.051	0.007	0.023	0.020	5.150	0.244	1.999	1.750	0.148	0.024	0.064	0.061	679	629	597	631	12.4	13.6	14.2	13.5
2007 Dodge Ram	FTP2	E10	5/16/2012	0.292	0.012	0.050	0.080	0.248	0.005	0.032	0.063	0.050	0.007	0.021	0.020	3.867	0.169	1.641	1.341	0.111	0.019	0.037	0.043	657	599	579	605	12.9	14.3	14.7	14.1
2007 Dodge Ram	FTP3	E10	5/18/2012	0.308	0.013	0.041	0.082	0.262	0.006	0.021	0.063	0.052	0.008	0.023	0.022	4.050	0.199	1.892	1.464	0.139	0.021	0.058	0.056	669	603	617	620	12.6	14.2	13.8	13.7
2007 Dodge Ram	FTP4	E10	7/6/2012	0.242	0.012	0.044	0.068	0.200	0.005	0.021	0.050	0.048	0.008	0.027	0.021	3.887	0.190	1.795	1.397	0.115	0.024	0.061	0.053	670	593	584	607	12.6	14.4	14.6	14.0
2007 Dodge Ram	FTP1	E15	6/19/2012	0.323	0.011	0.054	0.088	0.279	0.004	0.033	0.070	0.051	0.007	0.023	0.021	3.653	0.192	1.427	1.256	0.105	0.019	0.044	0.044	645	577	573	590	12.8	14.5	14.5	14.1
2007 Dodge Ram	FTP2	E15	6/20/2012	0.338	0.012	0.057	0.092	0.294	0.007	0.033	0.074	0.051	0.006	0.028	0.021	3.576	0.167	1.996	1.381	0.113	0.014	0.051	0.045	642	582	565	590	12.9	14.3	14.7	14.1
2007 Dodge Ram	FTP3	E15	6/21/2012	0.354	0.014	0.057	0.096	0.304	0.007	0.033	0.076	0.057	0.008	0.027	0.023	4.056	0.183	1.819	1.441	0.126	0.020	0.058	0.052	641	580	571	590	12.9	14.4	14.6	14.1
2007 Dodge Ram	FTP1	E20	6/5/2012	0.327	0.011	0.033	0.082	0.285	0.005	0.014	0.065	0.049	0.007	0.022	0.020	4.153	0.222	1.625	1.411	0.107	0.024	0.051	0.048	658	581	587	598	12.3	14.1	13.9	13.6
2007 Dodge Ram	FTP2	E20	6/6/2012	0.227	0.011	0.033	0.062	0.187	0.005	0.015	0.046	0.046	0.007	0.021	0.019	3.912	0.252	1.572	1.377	0.096	0.017	0.057	0.044	659	583	585	600	12.3	14.0	13.9	13.6
2007 Dodge Ram	FTP3	E20	6/8/2012	0.486	0.012	0.045	0.120	0.436	0.006	0.026	0.102	0.058	0.007	0.022	0.022	5.160	0.224	1.846	1.705	0.118	0.014	0.041	0.043	654	589	578	600	12.3	13.9	14.1	13.6
2007 Dodge Ram	FTP1	iBut16	5/30/2012	0.307	0.010	0.038	0.079	0.268	0.005	0.023	0.065	0.044	0.006	0.017	0.017	3.535	0.172	1.410	1.207	0.110	0.016	0.035	0.041	656	586	577	598	13.0	14.7	14.9	14.4
2007 Dodge Ram	FTP2	iBut16	5/31/2012	0.675	0.014	0.052	0.162	0.630	0.008	0.032	0.144	0.052	0.007	0.023	0.021	5.235	0.164	1.861	1.689	0.149	0.017	0.056	0.056	662	592	578	603	12.8	14.6	14.9	14.3
2007 Dodge Ram	FTP3	iBut16	6/1/2012	0.541	0.014	0.039	0.131	0.498	0.007	0.022	0.114	0.049	0.008	0.019	0.019	4.893	0.195	1.589	1.559	0.122	0.027	0.053	0.054	667	605	583	612	12.8	14.3	14.8	14.1
2007 Dodge Ram	UNI1	E10	5/19/2012	0.957	0.049	0.053	0.096	0.829	0.031	0.020	0.071	0.148	0.021	0.038	0.028	12.464	2.607	2.239	3.087	0.235	0.214	0.038	0.203	1159	621	918	669	7.2	13.7	9.3	12.7
2007 Dodge Ram	UNI2	E10	5/22/2012	0.689	0.043	0.065	0.077	0.570	0.027	0.027	0.054	0.137	0.018	0.045	0.026	12.177	2.176	3.029	2.747	0.139	0.179	0.042	0.167	1179	626	937	676	7.1	13.6	9.1	12.6
2007 Dodge Ram	UNI3	E10	5/23/2012	1.135	0.042	0.068	0.102	1.027	0.028	0.027	0.081	0.125	0.017	0.047	0.024	10.203	1.782	3.552	2.352	0.114	0.131	0.029	0.123	1084	608	903	653	7.7	14.0	9.4	13.0
2007 Dodge Ram	UNI1	E15	6/22/2012	1.033	0.047	0.080	0.101	0.895	0.029	0.035	0.074	0.159	0.021	0.053	0.031	13.497	2.278	2.971	2.910	0.200	0.195	0.040	0.185	1112	593	925	642	7.4	14.0	9.0	12.9
2007 Dodge Ram	UNI2	E15	7/3/2012	0.689	0.046	0.073	0.081	0.564	0.030	0.029	0.058	0.144	0.018	0.051	0.027	10.778	1.954	2.288	2.435	0.120	0.142	0.040	0.134	1141	607	927	657	7.2	13.7	9.0	12.6
2007 Dodge Ram	UNI3	E15	7/4/2012	1.089	0.044	0.049	0.098	0.963	0.027	0.013	0.074	0.146	0.021	0.042	0.028	9.767	1.903	1.391	2.271	0.201	0.163	0.038	0.156	1207	637	925	686	6.8	13.1	9.0	12.1
2007 Dodge Ram	UNI1	E20	6/12/2012	0.818	0.037	0.079	0.080	0.673	0.023	0.026	0.057	0.167	0.016	0.062	0.027	14.893	1.878	3.867	2.695	0.259	0.173	0.037	0.168	1204	611	926	664	6.6	13.3	8.8	12.2
2007 Dodge Ram	UNI2	E20	6/13/2012	0.652	0.032	0.062	0.066	0.538	0.018	0.022	0.046	0.132	0.016	0.047	0.024	11.835	1.726	3.248	2.355	0.107	0.128	0.033	0.120	1136	605	906	653	7.1	13.5	9.0	12.4
2007 Dodge Ram	UNI3	E20	6/14/2012	0.819	0.033	0.068	0.076	0.713	0.020	0.024	0.056	0.122	0.015	0.051	0.023	11.330	1.578	3.804	2.238	0.107	0.132	0.037	0.124	1121	608	914	656	7.2	13.4	8.9	12.4
2007 Dodge Ram	UNI1	iBut16	5/24/2012	0.598	0.036	0.062	0.067	0.498	0.022	0.026	0.047	0.116	0.016	0.042	0.023	10.476	1.999	2.886	2.504	0.113	0.147	0.042	0.138	1145	615	906	663	7.4	14.0	9.5	13.0
2007 Dodge Ram	UNI2	iBut16	5/25/2012	0.536	0.032	0.054	0.060	0.449	0.020	0.018	0.042	0.101	0.014	0.042	0.020	8.783	1.638	3.180	2.122	0.098	0.124	0.034	0.116	1137	613	926	663	7.5	14.0	9.3	13.0
2007 Dodge Ram	UNI3	iBut16	5/26/2012	0.795	0.029	0.043	0.070	0.681	0.019	0.015	0.053	0.131	0.011	0.032	0.019	11.965	1.240	2.666	1.903	0.142	0.103	0.034	0.100	1187	597	915	650	7.2	14.4	9.4	13.2

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	PN #/mile				Black Carbon µg/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	PN-1	PN-2	PN-3	PN-w	BC-1	BC-2	BC-3	BC-w
2007 Dodge Ram	FTP1	E10	5/15/2012	37.5	145.8	452.8	83.6	296.9	97.7	1237.4	1365.9	1.84E+12	3.22E+11	3.46E+11	6.43E+11	4.93E+02	6.56E+02	5.13E+02	3.92E+02
2007 Dodge Ram	FTP2	E10	5/16/2012	36.3	153.2	312.9	62.8	231.1	73.3	1211.4	980.1	NA	NA	NA	NA	4.92E+02	4.65E+02	3.98E+02	3.12E+02
2007 Dodge Ram	FTP3	E10	5/18/2012	26.2	167.1	368.2	71.7	266.2	82.4	1274.6	722.5	NA	NA	NA	NA	NA	NA	NA	NA
2007 Dodge Ram	FTP4	E10	7/6/2012	NA	NA	NA	NA	NA	NA	914.3	384.7	NA	NA	NA	NA	NA	NA	NA	NA
2007 Dodge Ram	FTP1	E15	6/19/2012	32.0	141.7	327.5	54.2	201.6	66.0	990.3	1175.7	2.10E+12	2.01E+11	2.01E+11	5.98E+11	4.02E+02	5.30E+02	2.08E+02	2.93E+02
2007 Dodge Ram	FTP2	E15	6/20/2012	20.2	74.2	171.0	31.3	121.7	40.9	1217.7	1405.8	7.40E+11	2.40E+11	3.66E+11	3.79E+11	3.73E+02	4.28E+02	2.11E+02	2.52E+02
2007 Dodge Ram	FTP3	E15	6/21/2012	26.9	162.4	411.8	73.0	269.1	87.9	1103.1	923.3	5.14E+11	2.22E+11	2.39E+11	2.87E+11	3.87E+02	5.20E+02	1.96E+02	2.85E+02
2007 Dodge Ram	FTP1	E20	6/5/2012	26.2	128.5	336.8	70.0	299.2	83.8	1505.8	2144.2	7.80E+11	2.05E+11	1.20E+11	3.00E+11	4.83E+02	3.68E+02	1.57E+02	2.47E+02
2007 Dodge Ram	FTP2	E20	6/6/2012	23.5	103.6	238.4	44.4	183.7	49.9	915.8	1410.5	6.14E+11	2.47E+11	1.93E+11	3.09E+11	3.41E+02	5.06E+02	1.30E+02	2.63E+02
2007 Dodge Ram	FTP3	E20	6/8/2012	39.0	171.4	495.6	99.4	411.0	114.7	1597.3	1633.1	1.34E+12	1.05E+11	1.50E+11	3.76E+11	3.97E+02	4.52E+02	1.26E+02	2.55E+02
2007 Dodge Ram	FTP1	iBut16	5/30/2012	40.9	164.5	384.8	68.7	235.8	80.1	1189.1	614.9	2.50E+12	1.87E+11	1.41E+11	6.52E+11	9.31E+02	2.99E+02	1.48E+02	3.15E+02
2007 Dodge Ram	FTP2	iBut16	5/31/2012	39.2	236.5	944.6	102.2	317.4	133.1	1560.3	641.0	2.07E+12	2.93E+11	2.41E+11	6.49E+11	6.51E+02	4.98E+02	2.94E+02	3.44E+02
2007 Dodge Ram	FTP3	iBut16	6/1/2012	NA	NA	NA	NA	NA	NA	1660.8	1289.3	1.53E+12	1.70E+11	3.08E+11	4.92E+11	2.62E+02	5.45E+02	1.76E+02	2.65E+02
2007 Dodge Ram	UNI1	E10	5/19/2012									3.29E+12	8.92E+11	2.98E+11	9.74E+11	5.96E+02	4.26E+02	4.15E+02	2.96E+02
2007 Dodge Ram	UNI2	E10	5/22/2012									2.65E+12	NA	4.18E+11	NA	1.45E+02	1.78E+02	3.93E+02	1.25E+02
2007 Dodge Ram	UNI3	E10	5/23/2012									NA	NA	NA	NA	NA	NA	NA	NA
2007 Dodge Ram	UNI1	E15	6/22/2012									7.80E+11	2.05E+11	1.20E+11	2.87E+11	6.43E+02	7.06E+02	5.04E+02	4.68E+02
2007 Dodge Ram	UNI2	E15	7/3/2012									6.14E+11	2.47E+11	1.93E+11	9.29E+11	4.59E+02	5.27E+02	4.70E+02	3.51E+02
2007 Dodge Ram	UNI3	E15	7/4/2012									NA	NA	NA	NA	6.73E+02	4.54E+02	NA	NA
2007 Dodge Ram	UNI1	E20	6/12/2012									7.80E+11	2.05E+11	1.20E+11	3.00E+11	4.41E+02	3.98E+02	1.92E+02	2.65E+02
2007 Dodge Ram	UNI2	E20	6/13/2012									6.14E+11	2.47E+11	1.93E+11	3.09E+11	9.79E+02	3.94E+02	3.27E+02	2.94E+02
2007 Dodge Ram	UNI3	E20	6/14/2012									1.34E+12	1.05E+11	1.50E+11	3.76E+11	9.25E+02	4.59E+02	3.30E+02	3.30E+02
2007 Dodge Ram	UNI1	iBut16	5/24/2012									3.15E+12	1.76E+12	3.49E+11	1.74E+12	6.97E+02	4.67E+02	2.93E+02	3.22E+02
2007 Dodge Ram	UNI2	iBut16	5/25/2012									2.87E+12	5.98E+11	1.26E+11	6.85E+11	9.56E+02	5.94E+02	4.13E+02	4.15E+02
2007 Dodge Ram	UNI3	iBut16	5/26/2012									NA	NA	NA	NA	NA	NA	NA	NA

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2012 Toyota Camry	FTP1	E10	8/10/2012	0.014	0.001	0.004	0.004	0.013	0.000	0.001	0.003	0.001	0.001	0.003	0.002	0.059	0.010	0.037	0.028	0.033	0.003	0.007	0.010	331	315	271	306	25.8	27.1	31.5	27.9
2012 Toyota Camry	FTP2	E10	8/14/2012	0.020	0.001	0.002	0.005	0.018	0.000	0.000	0.004	0.003	0.001	0.002	0.002	0.082	0.005	0.004	0.021	0.030	0.003	0.006	0.009	311	311	261	297	27.4	27.5	32.7	28.7
2012 Toyota Camry	FTP3	E10	8/16/2012	0.018	0.002	0.003	0.005	0.016	0.001	0.001	0.004	0.002	0.000	0.002	0.001	0.074	0.006	0.019	0.024	0.042	0.003	0.006	0.012	312	311	262	298	27.4	27.5	32.6	28.7
2012 Toyota Camry	FTP1	E15	9/14/2012	0.022	0.000	0.002	0.005	0.020	0.001	0.001	0.005	0.003	0.000	0.001	0.001	0.101	0.007	0.032	0.033	0.029	0.002	0.005	0.009	301	304	254	289	27.7	27.5	32.9	28.9
2012 Toyota Camry	FTP2	E15	9/18/2012	0.028	0.001	0.003	0.007	0.026	0.001	0.001	0.006	0.003	0.000	0.002	0.001	0.107	0.006	0.016	0.030	0.032	0.002	0.005	0.009	305	300	252	288	27.4	27.8	33.1	29.0
2012 Toyota Camry	FTP3	E15	9/20/2012	0.026	0.001	0.002	0.006	0.024	0.001	0.001	0.005	0.002	0.000	0.001	0.001	0.043	0.004	0.000	0.011	0.029	0.002	0.005	0.008	303	302	252	289	27.6	27.6	33.2	29.0
2012 Toyota Camry	FTP1	E20	8/24/2012	0.023	0.003	0.003	0.007	0.021	0.002	0.002	0.006	0.003	0.001	0.002	0.002	0.076	0.005	0.005	0.020	0.032	0.003	0.009	0.011	311	305	256	293	26.3	26.8	32.0	27.9
2012 Toyota Camry	FTP2	E20	9/6/2012	0.023	0.001	0.002	0.006	0.021	0.001	0.001	0.005	0.002	0.000	0.002	0.001	0.076	0.009	0.003	0.021	0.040	0.003	0.008	0.012	305	300	255	289	26.8	27.2	32.0	28.3
2012 Toyota Camry	FTP3	E20	9/7/2012	0.020	0.001	0.001	0.005	0.017	0.001	0.000	0.004	0.003	0.000	0.001	0.001	0.094	0.007	0.008	0.025	0.040	0.003	0.006	0.011	299	299	247	285	27.3	27.4	33.1	28.7
2012 Toyota Camry	FTP1	iBut16	7/18/2012	0.017	0.001	0.003	0.005	0.015	0.001	0.001	0.004	0.003	0.001	0.002	0.002	0.068	0.000	0.054	0.029	0.042	0.002	0.005	0.011	315	314	259	299	27.5	27.5	33.4	28.9
2012 Toyota Camry	FTP2	iBut16	7/24/2012	0.018	0.002	0.004	0.006	0.016	0.001	0.001	0.004	0.003	0.001	0.003	0.002	0.049	0.005	0.026	0.020	0.036	0.003	0.006	0.010	310	307	258	294	27.8	28.1	33.5	29.3
2012 Toyota Camry	FTP3	iBut16	7/25/2012	0.017	0.005	0.004	0.007	0.015	0.005	0.002	0.006	0.002	0.001	0.003	0.001	0.080	0.007	0.043	0.032	0.041	0.002	0.004	0.011	313	318	261	301	27.6	27.2	33.0	28.7
2012 Toyota Camry	FTP1	iBut24	11/20/2012	0.024	0.001	0.003	0.006	0.021	0.001	0.002	0.005	0.003	0.000	0.002	0.001	0.117	0.011	0.046	0.043	0.028	0.002	0.004	0.008	332	314	266	304	25.4	26.9	31.8	27.7
2012 Toyota Camry	FTP2	iBut24	11/30/2012	0.021	0.001	0.003	0.006	0.018	0.001	0.001	0.005	0.003	0.000	0.002	0.001	0.065	0.019	0.021	0.029	0.029	0.002	0.007	0.009	327	319	267	306	25.7	26.5	31.6	27.5
2012 Toyota Camry	FTP3	iBut24	12/4/2012	0.026	0.000	0.003	0.006	0.023	0.000	0.001	0.005	0.004	0.000	0.002	0.001	0.067	0.015	0.034	0.031	0.032	0.002	0.006	0.009	332	322	268	310	25.4	26.2	31.4	27.2
2012 Toyota Camry	FTP1	iBut32	12/12/2012	0.021	0.001	0.005	0.006	0.019	0.001	0.002	0.005	0.003	0.000	0.003	0.001	0.050	0.008	0.073	0.035	0.028	0.001	0.005	0.008	332	315	264	305	24.9	26.2	31.3	27.1
2012 Toyota Camry	FTP2	iBut32	12/13/2012	0.027	0.005	0.001	0.009	0.024	0.005	0.000	0.008	0.003	0.000	0.003	0.001	0.050	0.010	0.072	0.036	0.037	0.002	0.004	0.010	333	318	266	307	24.9	26.0	31.1	27.0
2012 Toyota Camry	FTP3	iBut32	12/14/2012	0.022	0.002	0.005	0.007	0.018	0.001	0.003	0.005	0.004	0.001	0.003	0.002	0.059	0.005	0.093	0.041	0.041	0.002	0.005	0.011	332	319	262	306	24.9	25.9	31.5	27.0
2012 Toyota Camry	FTP1	E10/iBut8	8/1/2012	0.016	0.003	0.003	0.006	0.013	0.002	0.002	0.004	0.003	0.001	0.002	0.002	0.078	0.002	0.037	0.027	0.031	0.002	0.004	0.009	316	311	258	297	26.6	27.0	32.6	28.3
2012 Toyota Camry	FTP2	E10/iBut8	8/2/2012	0.022	0.007	0.004	0.009	0.020	0.006	0.002	0.008	0.002	0.000	0.002	0.001	0.101	0.001	0.018	0.027	0.041	0.003	0.005	0.011	317	317	261	302	26.5	26.5	32.2	27.8
2012 Toyota Camry	FTP3	E10/iBut8	8/3/2012	0.020	0.001	0.002	0.005	0.018	0.000	0.000	0.004	0.002	0.001	0.002	0.002	0.095	0.000	0.026	0.027	0.043	0.002	0.004	0.011	328	316	265	304	25.6	26.6	31.8	27.6
2012 Toyota Camry	UNI1	E10	8/17/2012	0.043	0.002	0.003	0.005	0.036	0.001	0.001	0.003	0.008	0.001	0.003	0.002	0.078	0.033	0.025	0.035	0.110	0.007	0.010	0.013	538	306	390	324	15.9	27.9	21.9	26.4
2012 Toyota Camry	UNI2	E10	8/21/2012	0.047	0.002	0.004	0.005	0.042	0.002	0.002	0.004	0.007	0.001	0.003	0.001	0.060	0.017	0.001	0.018	0.091	0.007	0.007	0.011	549	307	403	326	15.6	27.8	21.2	26.2
2012 Toyota Camry	UNI3	E10	8/22/2012	0.055	0.002	0.005	0.005	0.048	0.001	0.001	0.004	0.008	0.001	0.005	0.002	0.053	0.039	0.014	0.038	0.115	0.007	0.009	0.012	559	304	398	323	15.3	28.1	21.4	26.4
2012 Toyota Camry	UNI1	E15	9/21/2012	0.068	0.002	0.002	0.005	0.061	0.002	0.001	0.005	0.008	0.000	0.002	0.001	0.128	0.017	0.000	0.022	0.127	0.006	0.008	0.012	527	291	381	309	15.8	28.7	21.9	27.0
2012 Toyota Camry	UNI2	E15	9/25/2012	0.062	0.002	0.004	0.005	0.055	0.002	0.001	0.005	0.008	0.000	0.003	0.001	0.131	0.036	0.000	0.038	0.080	0.005	0.008	0.009	515	289	367	307	16.2	28.9	22.8	27.2
2012 Toyota Camry	UNI3	E15	9/26/2012	0.077	0.002	0.001	0.006	0.068	0.002	0.000	0.005	0.010	0.001	0.002	0.001	0.123	0.019	0.007	0.023	0.088	0.006	0.006	0.010	530	290	386	309	15.8	28.8	21.7	27.0
2012 Toyota Camry	UNI1	E20	9/11/2012	0.084	0.002	0.006	0.006	0.075	0.001	0.002	0.005	0.011	0.001	0.004	0.001	0.250	0.020	0.007	0.031	0.088	0.007	0.009	0.012	533	296	398	315	15.3	27.7	20.6	26.0
2012 Toyota Camry	UNI2	E20	9/12/2012	0.058	0.003	0.005	0.006	0.051	0.002	0.002	0.004	0.008	0.001	0.004	0.002	0.087	0.023	0.000	0.025	0.112	0.005	0.010	0.011	539	296	396	315	15.2	27.6	20.7	26.0
2012 Toyota Camry	UNI3	E20	9/13/2012	0.102	0.003	0.004	0.008	0.090	0.002	0.001	0.007	0.013	0.001	0.003	0.002	0.442	0.025	0.005	0.045	0.104	0.007	0.006	0.011	540	297	397	317	15.1	27.5	20.6	25.8
2012 Toyota Camry	UNI1	iBut16	7/26/2012	0.052	0.003	0.004	0.006	0.046	0.002	0.000	0.004	0.007	0.001	0.004	0.002	0.080	0.032	0.005	0.033	0.129	0.005	0.012	0.012	546	305	395	324	15.8	28.3	21.9	26.7
2012 Toyota Camry	UNI2	iBut16	7/27/2012	0.050	0.002	0.003	0.005	0.044	0.001	0.000	0.003	0.007	0.001	0.004	0.002	0.052	0.022	0.011	0.022	0.107	0.006	0.009	0.011	558	304	385	322	15.5	28.4	22.4	26.8
2012 Toyota Camry	UNI3	iBut16	7/31/2012	0.060	0.007	0.004	0.009	0.053	0.005	0.001	0.007	0.009	0.001	0.004	0.002	0.114	0.052	0.000	0.052	0.098	0.004	0.008	0.009	558	305	394	325	15.5	28.3	21.9	26.6
2012 Toyota Camry	UNI1	iBut24	12/5/2012	0.083	0.001	0.004	0.006	0.075	0.000	0.004	0.004	0.009	0.001	0.001	0.001	0.079	0.042	0.014	0.042	0.097	0.005	0.005	0.010	587	306	410	327	14.3	27.6	20.6	25.8
2012 Toyota Camry	UNI2	iBut24	12/6/2012	0.089	0.005	0.024	0.011	0.082	0.005	0.020	0.010	0.008	0.001	0.004	0.001	0.084	0.050	0.020	0.049	0.084	0.005	0.007	0.009	586	307	407	328	14.4	27.5	20.7	25.7
2012 Toyota Camry	UNI3	iBut24	12/7/2012	0.058	0.002	0.005	0.005	0.052	0.001	0.001	0.004	0.007	0.001	0.004	0.001	0.093	0.047	0.015	0.048	0.086	0.005	0.008	0.009	573	310	400	330	14.7	27.2	21.1	25.6
2012 Toyota Camry	UNI1	iBut32	12/18/2012	0.067	0.001	0.006	0.005	0.059	0.001	0.002	0.004	0.009	0.000	0.005	0.001	0.153	0.059	0.011	0.061	0.088	0.004	0.007	0.009	596	310	409	332	13.9	26.6	20.2	24.9
2012 Toyota Camry	UNI2	iBut32	12/19/2012	0.086	0.002	0.001	0.006	0.077	0.002	0.002	0.006	0.011	0.000	0.000	0.001	0.085	0.039	0.005	0.039	0.110	0.005	0.007	0.010	603	316	408	337	13.7	26.2	20.3	24.5
2012 Toyota Camry	UNI3	iBut32	12/20/2012	0.071	0.002	0.002	0.006	0.063	0.001	0.001	0.005	0.009	0.001	0.002	0.001	0.100	0.048	0.022	0.049	0.099	0.005	0.003	0.009	604	315	418	337	13.7	26.2	19.8	24.5
2012 Toyota Camry	UNI1	E10/iBut8	8/7/2012	0.049	0.003	0.001	0.005	0.041	0.002	0.000	0.004	0.008	0.001	0.001	0.001	0.080	0.033	0.006	0.033	0.103	0.006	0.006	0.011	569	307	411	328	14.8	27.3	20.5	25.6
2012 Toyota Camry	UNI2	E10/iBut8	8/8/2012	0.043	0.002	0.003	0.004	0.038	0.001	0.001	0.003	0.005	0.001	0.003	0.001	0.071	0.024	0.013	0.026	0.135	0.005	0.007	0.012	564	307	402	327	14.9	27.4	20.9	25.7
2012 Toyota Camry	UNI3	E10/iBut8	8/9/2012	0.047	0.002	0.003	0.005	0.042	0.001	0.000	0.003	0.006	0.001	0.003	0.002	0.074	0.049	0.010	0.048	0.117	0.005	0.009	0.011	570	309	403	329	14.7	27.2	20.8	25.5

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile				Black Carbon µg/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w	BC-1	BC-2	BC-3	BC-w
2012 Toyota Camry	FTP1	E10	8/10/2012	0.9	9.4	28.8	4.3	9.4	2.5	308.5	348.6		-0.08	1.88E+12	4.94E+11	2.79E+11	7.22E+11	5.12E+01	2.69E+01	1.23E+01	2.79E+01
2012 Toyota Camry	FTP2	E10	8/14/2012	NA	NA	NA	NA	NA	NA	596.8	478.5		0.01	2.27E+12	5.77E+11	5.03E+11	9.08E+11	3.31E+01	2.68E+01	2.79E+01	2.84E+01
2012 Toyota Camry	FTP3	E10	8/16/2012	1.2	10.6	26.9	3.7	9.7	2.6	245.4	493.5		-0.01	2.01E+12	6.39E+11	5.59E+11	9.02E+11	NA	NA	NA	NA
2012 Toyota Camry	FTP1	E15	9/14/2012	0.9	16.0	25.9	3.9	11.0	3.7	287.7	165.1		-0.10	4.67E+12	3.15E+12	3.80E+11	7.82E+11	2.95E+01	3.81E+01	1.94E+01	3.12E+01
2012 Toyota Camry	FTP2	E15	9/18/2012	1.6	12.6	30.9	5.4	14.0	4.8	547.4	739.9		-0.06	1.81E+12	5.51E+11	4.42E+11	7.97E+11	3.73E+01	2.90E+01	1.11E+01	2.58E+01
2012 Toyota Camry	FTP3	E15	9/20/2012	NA	NA	NA	NA	NA	NA	432.2	217.6		NA	2.16E+12	5.40E+11	2.52E+11	6.83E+11	5.11E+01	4.88E+01	1.52E+01	4.00E+01
2012 Toyota Camry	FTP1	E20	8/24/2012	NA	NA	NA	NA	NA	NA	236.9	138.6		-0.09	1.72E+12	5.24E+11	3.37E+11	7.21E+11	3.53E+01	3.76E+01	2.83E+01	3.46E+01
2012 Toyota Camry	FTP2	E20	9/6/2012	2.0	13.3	22.2	4.1	12.8	3.0	560.6	271.0		-0.12	1.60E+12	4.91E+11	3.64E+11	6.86E+11	2.60E+01	2.24E+01	1.52E+01	2.12E+01
2012 Toyota Camry	FTP3	E20	9/7/2012	2.2	13.0	23.1	3.8	9.4	2.6	510.7	201.6		0.04	1.45E+12	6.71E+11	2.65E+11	7.22E+11	3.22E+01	3.34E+01	1.32E+01	2.76E+01
2012 Toyota Camry	FTP1	iBut16	7/18/2012	NA	NA	NA	NA	NA	NA	331.8	340.3		NA	2.11E+12	8.53E+11	7.03E+11	1.07E+12	6.60E+01	3.92E+01	5.71E+01	4.97E+01
2012 Toyota Camry	FTP2	iBut16	7/24/2012	1.2	12.5	42.8	5.3	9.7	3.4	321.6	319.9		NA	1.75E+12	8.72E+11	7.06E+11	1.01E+12	9.77E+01	9.49E+01	7.90E+01	9.11E+01
2012 Toyota Camry	FTP3	iBut16	7/25/2012	0.7	11.1	32.6	4.7	10.1	3.3	232.9	98.0		NA	NA	NA	NA	NA	5.35E+01	4.41E+01	3.14E+01	4.25E+01
2012 Toyota Camry	FTP1	iBut24	11/20/2012	0.8	15.1	24.4	3.3	11.2	3.5	341.7	223.3	94.6	0.01	1.33E+12	3.06E+11	2.15E+11	4.94E+11	2.21E+01	1.84E+01	1.71E+01	1.88E+01
2012 Toyota Camry	FTP2	iBut24	11/30/2012	0.8	14.0	28.7	4.6	12.5	4.2	270.0	101.3	115.6	0.03	1.73E+12	2.17E+11	2.29E+11	5.34E+11	2.05E+01	1.27E+01	9.29E+00	1.34E+01
2012 Toyota Camry	FTP3	iBut24	12/4/2012	1.3	21.4	38.2	5.9	16.0	4.6	256.2	244.4	167.5	0.29	2.00E+12	1.78E+11	1.07E+11	5.36E+11	3.99E+01	2.05E+01	1.14E+01	2.20E+01
2012 Toyota Camry	FTP1	iBut32	12/12/2012	1.9	13.5	28.0	2.6	6.8	2.2	269.6	216.6	30.9	0.24	1.21E+12	1.58E+11	2.83E+11	4.11E+11	4.44E+01	1.09E+01	8.35E+00	1.71E+01
2012 Toyota Camry	FTP2	iBut32	12/13/2012	1.3	13.2	23.6	3.1	8.4	2.5	311.2	159.1	134.7	0.48	1.14E+12	1.55E+11	1.74E+11	3.65E+11	2.35E+01	1.13E+01	1.56E+01	1.50E+01
2012 Toyota Camry	FTP3	iBut32	12/14/2012	1.6	14.0	30.6	3.8	8.9	2.8	394.0	176.3	103.5	0.27	NA	NA	NA	NA	NA	NA	NA	NA
2012 Toyota Camry	FTP1	E10/iBut8	8/1/2012	NA	NA	NA	NA	NA	NA	336.2	83.7		NA	1.90E+12	6.64E+11	5.18E+11	8.80E+11	5.26E+01	3.36E+01	3.24E+01	3.72E+01
2012 Toyota Camry	FTP2	E10/iBut8	8/2/2012	0.8	16.0	36.0	5.3	12.5	3.6	228.7	215.0		NA	1.76E+12	5.32E+11	3.51E+11	7.37E+11	6.80E+01	2.85E+01	2.57E+01	3.59E+01
2012 Toyota Camry	FTP3	E10/iBut8	8/3/2012	0.5	13.3	37.2	5.3	12.5	3.6	371.0	212.6		NA	NA	NA	NA	NA	5.58E+01	2.18E+01	2.18E+01	2.89E+01
2012 Toyota Camry	UNI1	E10	8/17/2012										0.12	4.42E+12	1.60E+12	7.03E+11	1.68E+12	1.42E+02	3.64E+01	6.31E+01	4.37E+01
2012 Toyota Camry	UNI2	E10	8/21/2012										0.03	4.56E+12	7.60E+11	1.17E+12	9.84E+11	1.04E+02	2.91E+01	6.93E+01	3.58E+01
2012 Toyota Camry	UNI3	E10	8/22/2012										NA	NA	NA	NA	NA	1.14E+02	2.80E+01	7.23E+01	3.55E+01
2012 Toyota Camry	UNI1	E15	9/21/2012										0.39	4.38E+12	3.51E+11	8.04E+11	5.90E+11	8.68E+01	1.85E+01	4.51E+01	2.38E+01
2012 Toyota Camry	UNI2	E15	9/25/2012										0.27	2.19E+12	3.94E+11	2.99E+11	4.80E+11	6.00E+01	1.13E+01	1.61E+01	1.42E+01
2012 Toyota Camry	UNI3	E15	9/26/2012										0.23	2.14E+12	4.19E+11	4.41E+11	5.10E+11	8.09E+01	3.18E+01	2.64E+01	3.39E+01
2012 Toyota Camry	UNI1	E20	9/11/2012										0.19	6.24E+12	2.30E+12	4.96E+11	2.38E+12	9.00E+01	2.09E+01	1.38E+01	2.40E+01
2012 Toyota Camry	UNI2	E20	9/12/2012										0.10	4.14E+12	5.60E+11	4.76E+11	7.38E+11	1.06E+02	2.37E+01	4.18E+01	2.91E+01
2012 Toyota Camry	UNI3	E20	9/13/2012										0.15	4.67E+12	3.15E+12	3.80E+11	3.04E+12	1.61E+02	3.67E+01	5.17E+01	4.41E+01
2012 Toyota Camry	UNI1	iBut16	7/26/2012										NA	5.12E+12	8.51E+11	6.19E+11	1.06E+12	7.79E+01	4.61E+01	1.96E+01	4.59E+01
2012 Toyota Camry	UNI2	iBut16	7/27/2012										NA	5.11E+12	8.75E+11	4.95E+11	1.07E+12	1.36E+02	4.38E+01	3.11E+01	4.77E+01
2012 Toyota Camry	UNI3	iBut16	7/31/2012										NA	4.56E+12	1.73E+12	9.75E+11	1.82E+12	1.27E+02	4.62E+01	9.08E+01	5.35E+01
2012 Toyota Camry	UNI1	iBut24	12/5/2012										0.36	5.18E+12	3.40E+12	1.56E+11	3.27E+12	1.24E+02	2.70E+01	2.22E+01	3.17E+01
2012 Toyota Camry	UNI2	iBut24	12/6/2012										0.14	4.64E+12	1.39E+12	5.30E+10	1.46E+12	1.52E+02	4.59E+01	6.88E+01	5.29E+01
2012 Toyota Camry	UNI3	iBut24	12/7/2012										0.20	5.43E+12	8.18E+11	4.72E+11	1.03E+12	NA	NA	NA	NA
2012 Toyota Camry	UNI1	iBut32	12/18/2012										1.25	3.73E+12	3.49E+11	2.34E+11	5.15E+11	9.13E+01	1.81E+01	1.82E+01	2.19E+01
2012 Toyota Camry	UNI2	iBut32	12/19/2012										1.03	3.61E+12	4.37E+11	2.38E+11	5.88E+11	8.55E+01	2.81E+01	2.55E+01	3.09E+01
2012 Toyota Camry	UNI3	iBut32	12/20/2012										0.94	2.01E+12	1.97E+11	1.19E+11	2.84E+11	9.97E+01	2.21E+01	1.70E+01	2.57E+01
2012 Toyota Camry	UNI1	E10/iBut8	8/7/2012										NA	3.48E+12	5.64E+11	5.54E+11	7.14E+11	1.13E+02	3.40E+01	4.38E+01	3.87E+01
2012 Toyota Camry	UNI2	E10/iBut8	8/8/2012										NA	4.82E+12	8.55E+11	7.36E+11	1.05E+12	1.01E+02	3.10E+01	6.29E+01	3.69E+01
2012 Toyota Camry	UNI3	E10/iBut8	8/9/2012										NA	NA	NA	NA	NA	1.12E+02	3.16E+01	8.01E+01	3.91E+01

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2012 Kia Optima	FTP1	E10	10/24/2012	0.031	0.001	0.001	0.008	0.029	0.002	0.001	0.007	0.003	0.000	0.000	0.001	0.301	0.000	0.000	0.063	0.008	0.003	0.002	0.004	315	324	262	305	27.1	26.4	32.7	28.0
2012 Kia Optima	FTP2	E10	10/25/2012	0.032	0.002	0.000	0.008	0.029	0.002	0.001	0.008	0.004	0.000	0.000	0.001	0.293	0.000	0.000	0.061	0.007	0.006	0.007	0.006	317	322	258	304	26.9	26.5	33.1	28.1
2012 Kia Optima	FTP3	E10	10/30/2012	0.026	0.002	0.000	0.006	0.023	0.003	0.001	0.006	0.004	0.000	0.000	0.001	0.204	0.000	0.001	0.042	0.009	0.003	0.002	0.004	313	327	264	307	27.3	26.1	32.4	27.9
2012 Kia Optima	FTP1	E15	1/23/2013	0.048	0.004	0.000	0.012	0.043	0.004	0.001	0.011	0.006	0.000	0.000	0.001	0.381	0.006	0.000	0.082	0.007	0.006	0.002	0.005	318	324	259	305	26.2	25.8	32.2	27.4
2012 Kia Optima	FTP2	E15	1/24/2013	0.048	0.002	0.001	0.012	0.043	0.002	0.001	0.010	0.006	0.000	0.000	0.001	0.315	0.006	0.000	0.069	0.009	0.004	0.004	0.005	322	323	260	305	25.9	25.9	32.2	27.4
2012 Kia Optima	FTP3	E15	1/31/2013	0.043	0.002	0.000	0.010	0.038	0.002	0.001	0.009	0.005	0.000	0.000	0.001	0.288	0.000	0.000	0.060	0.009	0.005	0.002	0.005	314	322	257	303	26.5	26.0	32.5	27.6
2012 Kia Optima	FTP1	E20	2/13/2013	0.065	0.002	0.002	0.015	0.059	0.003	0.001	0.014	0.008	0.000	0.001	0.002	0.515	0.000	0.000	0.107	0.005	0.005	0.003	0.004	318	320	254	301	25.7	25.6	32.2	27.1
2012 Kia Optima	FTP2	E20	2/15/2013	0.052	0.001	-0.002	0.011	0.048	0.002	0.000	0.011	0.005	0.000	0.000	0.001	0.254	0.000	0.000	0.053	0.008	0.005	0.003	0.005	312	318	255	299	26.2	25.8	32.1	27.3
2012 Kia Optima	FTP3	E20	2/19/2013	0.068	0.002	0.001	0.016	0.062	0.002	0.001	0.014	0.007	0.000	0.001	0.002	0.315	0.000	0.000	0.066	0.007	0.004	0.004	0.005	315	321	256	302	25.9	25.5	31.9	27.1
2012 Kia Optima	FTP1	iBut16	3/6/2013	0.035	0.002	0.001	0.009	0.031	0.002	0.001	0.008	0.005	0.000	0.000	0.001	0.317	0.000	0.000	0.066	0.008	0.004	0.004	0.005	322	323	255	304	26.8	26.8	33.9	28.4
2012 Kia Optima	FTP2	iBut16	3/7/2013	0.045	0.003	0.001	0.011	0.042	0.004	0.001	0.011	0.004	0.000	0.000	0.001	0.342	0.000	0.000	0.071	0.009	0.003	0.004	0.005	321	321	258	304	26.9	26.9	33.5	28.5
2012 Kia Optima	FTP3	iBut16	3/8/2013	0.050	0.002	0.001	0.012	0.044	0.002	0.000	0.010	0.007	0.000	0.001	0.002	0.539	0.000	0.000	0.112	0.005	0.004	0.003	0.004	315	317	253	299	27.3	27.3	34.1	28.9
2012 Kia Optima	FTP1	iBut24	1/3/2013	0.036	0.004	0.002	0.010	0.032	0.004	0.002	0.009	0.004	0.000	0.000	0.001	0.226	0.000	0.000	0.047	0.012	0.004	0.003	0.005	316	321	262	303	26.6	26.3	32.2	27.8
2012 Kia Optima	FTP2	iBut24	1/9/2013	0.027	0.002	0.002	0.007	0.024	0.002	0.001	0.007	0.003	0.000	0.000	0.001	0.184	0.000	0.002	0.039	0.008	0.005	0.004	0.005	312	316	259	299	27.0	26.7	32.5	28.2
2012 Kia Optima	FTP3	iBut24	1/10/2013	0.034	0.002	0.001	0.008	0.031	0.002	0.001	0.008	0.004	0.000	0.000	0.001	0.403	0.031	0.002	0.100	0.007	0.001	0.004	0.003	325	324	264	308	25.9	26.0	31.9	27.4
2012 Kia Optima	FTP1	iBut32	2/26/2013	0.058	0.002	0.001	0.013	0.051	0.002	0.001	0.012	0.008	0.000	0.000	0.002	0.483	0.000	0.000	0.101	0.004	0.003	0.004	0.004	320	319	255	302	25.8	25.9	32.4	27.4
2012 Kia Optima	FTP2	iBut32	2/27/2013	0.041	0.002	0.001	0.010	0.037	0.002	0.001	0.009	0.004	0.000	0.000	0.001	0.218	0.031	0.000	0.062	0.007	0.004	0.003	0.004	310	315	254	297	26.6	26.3	32.5	27.8
2012 Kia Optima	FTP3	iBut32	2/28/2013	0.044	0.002	0.001	0.011	0.039	0.002	0.001	0.009	0.006	0.000	0.000	0.002	0.312	0.000	0.000	0.065	0.008	0.004	0.003	0.004	320	319	254	301	25.8	26.0	32.6	27.5
2012 Kia Optima	FTP1	E10/iBut8	10/12/2012	0.037	0.002	0.001	0.009	0.033	0.002	0.000	0.008	0.004	0.000	0.000	0.001	0.239	0.000	0.002	0.050	0.009	0.005	0.002	0.005	320	337	268	314	26.2	25.0	31.4	26.7
2012 Kia Optima	FTP2	E10/iBut8	10/16/2012	0.044	0.003	0.000	0.011	0.041	0.004	0.000	0.010	0.004	0.000	0.000	0.001	0.233	0.000	0.000	0.048	0.011	0.006	0.005	0.006	316	331	261	309	26.5	25.4	32.2	27.2
2012 Kia Optima	FTP3	E10/iBut8	10/17/2012	0.035	0.003	0.002	0.009	0.032	0.003	0.002	0.009	0.003	0.000	0.000	0.001	0.208	0.017	0.001	0.052	0.009	0.003	0.003	0.004	321	335	263	312	26.2	25.1	31.9	26.9
2012 Kia Optima	UNI1	E10	10/18/2012	0.088	0.003	0.002	0.007	0.078	0.003	0.001	0.006	0.012	0.000	0.001	0.001	1.464	0.064	0.000	0.131	0.007	0.006	0.006	0.006	544	298	413	318	15.6	28.7	20.7	26.8
2012 Kia Optima	UNI2	E10	10/19/2012	0.091	0.003	0.000	0.008	0.079	0.003	0.000	0.007	0.014	0.000	0.000	0.001	0.894	0.059	0.000	0.098	0.019	0.006	0.003	0.006	554	296	417	317	15.4	28.9	20.5	26.9
2012 Kia Optima	UNI2	E10	10/23/2012	0.105	0.002	0.001	0.007	0.095	0.002	0.000	0.006	0.011	0.000	0.001	0.001	0.870	0.102	0.000	0.134	0.024	0.006	0.011	0.007	564	299	415	321	15.1	28.5	20.6	26.6
2012 Kia Optima	UNI1	E15	1/11/2013	0.193	0.002	0.000	0.012	0.179	0.003	0.000	0.011	0.016	0.000	0.000	0.001	1.340	0.032	0.000	0.097	0.017	0.007	0.008	0.007	576	290	415	313	14.4	28.9	20.1	26.7
2012 Kia Optima	UNI2	E15	1/16/2013	0.155	0.004	0.000	0.011	0.140	0.004	0.000	0.011	0.017	0.000	0.001	0.001	1.122	0.005	0.000	0.061	0.018	0.006	0.009	0.007	574	295	421	318	14.5	28.3	19.9	26.3
2012 Kia Optima	UNI2	E15	1/18/2013	0.109	0.003	0.003	0.008	0.098	0.003	0.002	0.008	0.013	0.000	0.001	0.001	0.901	0.011	0.000	0.056	0.025	0.006	0.009	0.007	577	299	422	322	14.4	27.9	19.8	26.0
2012 Kia Optima	UNI1	E20	2/1/2013	0.147	0.003	0.000	0.010	0.129	0.003	0.000	0.009	0.021	0.001	0.001	0.002	0.998	0.042	0.000	0.089	0.022	0.008	0.010	0.009	583	287	400	310	14.0	28.5	20.4	26.4
2012 Kia Optima	UNI2	E20	2/5/2013	0.167	0.003	0.007	0.011	0.148	0.002	0.006	0.010	0.022	0.000	0.000	0.001	1.418	0.036	0.000	0.104	0.012	0.007	0.006	0.008	561	287	417	310	14.5	28.5	19.6	26.4
2012 Kia Optima	UNI3	E20	2/6/2013	0.146	0.002	0.004	0.010	0.131	0.002	0.002	0.009	0.017	0.000	0.002	0.001	1.392	0.010	0.000	0.080	0.008	0.008	0.010	0.008	561	287	408	309	14.5	28.5	20.1	26.5
2012 Kia Optima	UNI1	iBut16	3/1/2013	0.394	0.004	0.002	0.024	0.354	0.004	0.001	0.022	0.046	0.000	0.001	0.002	1.174	0.015	0.000	0.073	0.011	0.007	0.007	0.007	547	297	428	319	15.7	29.1	20.2	27.1
2012 Kia Optima	UNI2	iBut16	3/4/2013	0.126	0.007	0.018	0.014	0.112	0.007	0.017	0.013	0.016	0.000	0.001	0.001	1.335	0.020	0.000	0.087	0.030	0.007	0.005	0.008	601	303	421	326	14.3	28.6	20.5	26.5
2012 Kia Optima	UNI3	iBut16	3/5/2013	0.095	0.002	0.005	0.007	0.086	0.003	0.000	0.007	0.011	0.000	0.006	0.001	0.995	0.024	0.000	0.071	0.014	0.006	0.010	0.007	558	281	396	303	15.4	30.7	21.8	28.5
2012 Kia Optima	UNI1	iBut24	12/27/2012	0.111	0.003	0.001	0.008	0.096	0.003	0.002	0.007	0.017	0.000	0.000	0.001	1.651	0.043	0.000	0.123	0.015	0.007	0.009	0.007	575	290	410	312	14.6	29.1	20.5	27.0
2012 Kia Optima	UNI2	iBut24	12/28/2012	0.121	0.003	0.002	0.009	0.107	0.003	0.002	0.008	0.017	0.000	0.001	0.001	1.556	0.008	0.000	0.087	0.008	0.006	0.006	0.006	579	292	418	315	14.5	28.9	20.2	26.8
2012 Kia Optima	UNI3	iBut24	1/4/2013	0.106	0.003	0.000	0.008	0.089	0.003	0.001	0.007	0.020	0.000	0.000	0.001	1.285	0.025	0.000	0.088	0.021	0.006	0.010	0.007	593	295	417	319	14.2	28.6	20.2	26.5
2012 Kia Optima	UNI1	iBut32	2/21/2013	0.204	0.003	0.002	0.013	0.179	0.004	0.002	0.012	0.029	0.000	0.001	0.002	2.533	0.081	0.000	0.202	0.009	0.005	0.011	0.006	588	295	418	318	14.0	28.0	19.8	26.0
2012 Kia Optima	UNI2	iBut32	2/22/2013	0.115	0.002	0.002	0.008	0.109	0.002	0.002	0.008	0.007	0.000	0.001	0.000	0.836	0.022	0.000	0.063	0.005	0.008	0.004	0.007	541	292	414	313	15.2	28.4	20.0	26.4
2012 Kia Optima	UNI2	iBut32	2/25/2013	0.118	0.003	0.004	0.009	0.103	0.003	0.003	0.009	0.017	0.000	0.000	0.001	1.029	0.006	0.000	0.058	0.023	0.007	0.008	0.007	575	287	407	311	14.3	28.8	20.3	26.6
2012 Kia Optima	UNI1	E10/iBut8	10/9/2012	0.075	0.003	0.002	0.006	0.067	0.002	0.000	0.006	0.009	0.000	0.002	0.001	0.618	0.030	0.000	0.059	0.019	0.009	0.003	0.009	537	292	410	313	15.6	28.8	20.5	26.8
2012 Kia Optima	UNI2	E10/iBut8	10/10/2012	0.072	0.001	0.002	0.005	0.063	0.001	0.000	0.004	0.010	0.000	0.002	0.001	0.623	0.035	0.000	0.063	0.024	0.008	0.012	0.009	570	299	419	321	14.7	28.1	20.1	26.2
2012 Kia Optima	UNI3	E10/iBut8	10/11/2012	0.089	0.002	0.000	0.006	0.081	0.002	0.000	0.006	0.010	0.000	0.001	0.001	0.594	0.007	0.000	0.037	0.026	0.007	0.012	0.008	561	300	415	322	15.0	28.0	20.3	26.1

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile				Black Carbon µg/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w	BC-1	BC-2	BC-3	BC-w
2012 Kia Optima	FTP1	E10	10/24/2012	1.3	23.7	23.3	1.3	7.6	2.2	563.7	320.1	72.7	4.53	2.23E+13	5.19E+12	3.22E+12	8.20E+12	5.17E+01	1.29E+01	6.47E+00	7.69E+02
2012 Kia Optima	FTP2	E10	10/25/2012	2.3	28.3	41.9	7.5	20.5	6.1	365.0	267.3	100.4	4.27	2.19E+13	4.75E+12	3.41E+12	7.93E+12	3.49E+01	1.26E+01	1.12E+01	6.80E+02
2012 Kia Optima	FTP3	E10	10/30/2012	1.3	18.2	19.0	4.4	11.1	3.4	461.0	421.0	0.0	4.18	2.18E+13	4.68E+12	3.26E+12	7.84E+12	4.45E+01	1.28E+01	7.12E+00	7.23E+02
2012 Kia Optima	FTP1	E15	1/23/2013	2.8	40.6	84.2	9.3	23.4	8.8	NA	NA	NA	4.61	1.80E+13	3.27E+12	2.00E+12	5.98E+12	7.23E+01	1.15E+01	7.43E+00	8.85E+02
2012 Kia Optima	FTP2	E15	1/24/2013	NA	NA	NA	NA	NA	NA	108.2	19.7	59.7	4.22	1.78E+13	3.13E+12	1.84E+12	5.84E+12	3.87E+01	1.12E+01	NA	NA
2012 Kia Optima	FTP3	E15	1/31/2013	3.1	32.6	74.9	11.9	36.3	12.0	131.0	168.8	101.8	4.08	1.96E+13	3.65E+12	2.62E+12	6.70E+12	6.22E+01	1.17E+01	9.99E+00	8.47E+02
2012 Kia Optima	FTP1	E20	2/13/2013	7.1	70.8	100.5	19.6	63.6	17.5	NA	NA	NA	4.29	2.06E+13	2.18E+12	1.68E+12	5.87E+12	4.78E+01	1.10E+01	1.00E+01	7.32E+02
2012 Kia Optima	FTP2	E20	2/15/2013	5.3	37.4	57.4	11.8	37.5	10.5	53.0	24.3	89.4	3.88	1.72E+13	2.25E+12	2.09E+12	5.31E+12	5.03E+01	1.14E+01	7.37E+00	7.28E+02
2012 Kia Optima	FTP3	E20	2/19/2013	6.0	51.1	63.1	16.3	52.1	14.4	58.2	94.5	0.0	3.98	1.95E+13	2.11E+12	2.05E+12	5.71E+12	3.34E+01	1.13E+01	6.80E+00	6.00E+02
2012 Kia Optima	FTP1	iBut16	3/6/2013	2.9	38.4	60.8	9.2	24.1	7.5	229.1	59.8	153.0	6.90	2.78E+13	8.47E+12	5.95E+12	1.18E+13	3.80E+01	8.44E+00	7.69E+00	5.62E+02
2012 Kia Optima	FTP2	iBut16	3/7/2013	5.3	56.8	83.6	13.9	32.3	10.1	187.4	218.2	171.6	7.06	2.74E+13	8.67E+12	5.80E+12	1.18E+13	3.32E+01	8.92E+00	9.14E+00	5.57E+02
2012 Kia Optima	FTP3	iBut16	3/8/2013	2.5	47.0	65.9	10.8	27.3	10.4	158.8	65.9	125.6	7.37	2.80E+13	8.29E+12	5.17E+12	1.15E+13	9.33E+01	9.05E+00	7.52E+00	9.60E+02
2012 Kia Optima	FTP1	iBut24	1/3/2013	4.0	22.5	41.1	7.7	24.4	7.3	397.0	299.9	344.3	5.57	2.20E+13	5.94E+12	2.97E+12	8.47E+12	7.21E+01	1.59E+01	8.23E+00	1.01E+03
2012 Kia Optima	FTP2	iBut24	1/9/2013	1.8	14.5	25.6	4.8	15.7	5.1	457.0	248.0	0.0	4.22	2.04E+13	4.96E+12	2.61E+12	7.52E+12	4.72E+01	1.16E+01	9.95E+00	7.37E+02
2012 Kia Optima	FTP3	iBut24	1/10/2013	2.7	29.3	43.4	7.9	23.4	7.1	255.8	127.6	0.0	4.45	2.05E+13	4.09E+12	2.38E+12	7.03E+12	5.14E+01	1.21E+01	1.53E+01	8.31E+02
2012 Kia Optima	FTP1	iBut32	2/26/2013	3.6	62.7	116.6	13.3	31.7	9.7	149.1	37.1	98.1	1.92	1.39E+13	4.44E+11	7.02E+11	3.32E+12	NA	NA	NA	NA
2012 Kia Optima	FTP2	iBut32	2/27/2013	2.9	37.0	80.9	8.4	23.5	7.4	90.6	45.1	173.2	1.50	1.33E+13	4.51E+11	7.01E+11	3.20E+12	NA	NA	NA	NA
2012 Kia Optima	FTP3	iBut32	2/28/2013	2.5	10.5	15.0	2.0	7.0	1.8	123.4	70.0	192.2	1.98	NA	NA	NA	NA	NA	NA	NA	NA
2012 Kia Optima	FTP1	E10/iBut8	10/12/2012	7.4	16.0	40.1	7.0	21.6	6.3	428.5	249.1	203.9	3.29	1.75E+13	3.67E+12	2.76E+12	6.30E+12	3.68E+01	1.14E+01	8.65E+00	6.36E+02
2012 Kia Optima	FTP2	E10/iBut8	10/16/2012	1.8	27.8	47.5	9.8	30.4	9.2	650.3	494.5	112.6	3.13	1.70E+13	3.59E+12	2.71E+12	6.14E+12	3.81E+01	9.49E+00	7.58E+00	5.84E+02
2012 Kia Optima	FTP3	E10/iBut8	10/17/2012	2.7	21.7	43.8	7.6	24.2	6.8	443.7	355.2	144.5	2.97	1.91E+13	4.29E+12	3.41E+12	7.13E+12	4.21E+01	1.05E+01	5.58E+00	6.29E+02
2012 Kia Optima	UNI1	E10	10/18/2012										3.43	4.85E+13	7.48E+12	4.50E+12	9.37E+12	3.83E+01	1.74E+01	8.58E+00	6.21E+02
2012 Kia Optima	UNI2	E10	10/19/2012										NA	NA	NA	NA	NA	4.53E+01	1.62E+01	9.38E+00	6.18E+02
2012 Kia Optima	UNI2	E10	10/23/2012										4.84	NA	NA	NA	NA	4.74E+01	2.47E+01	9.52E+00	8.57E+02
2012 Kia Optima	UNI1	E15	1/11/2013										5.23	4.27E+13	5.71E+12	2.46E+12	7.38E+12	6.50E+01	2.08E+01	6.79E+00	8.07E+02
2012 Kia Optima	UNI2	E15	1/16/2013										7.71	4.10E+12	1.03E+12	1.54E+11	1.13E+12	1.14E+02	2.33E+01	NA	NA
2012 Kia Optima	UNI2	E15	1/18/2013										6.02	4.05E+13	5.33E+12	3.09E+12	6.97E+12	6.72E+01	2.25E+01	5.48E+00	8.47E+02
2012 Kia Optima	UNI1	E20	2/1/2013										4.17	3.91E+13	3.71E+12	2.39E+12	5.44E+12	1.02E+02	1.67E+01	8.16E+00	7.99E+02
2012 Kia Optima	UNI2	E20	2/5/2013										3.46	3.76E+13	4.05E+12	2.70E+12	5.69E+12	1.48E+01	1.80E+01	4.13E+00	5.61E+02
2012 Kia Optima	UNI3	E20	2/6/2013										3.23	3.38E+13	3.20E+12	2.47E+12	4.72E+12	6.99E+01	1.76E+01	8.68E+00	7.41E+02
2012 Kia Optima	UNI1	iBut16	3/1/2013										4.57	4.53E+13	7.40E+12	4.45E+12	9.14E+12	6.29E+01	1.40E+01	5.17E+00	6.01E+02
2012 Kia Optima	UNI2	iBut16	3/4/2013										7.56	5.99E+13	1.00E+13	7.51E+12	1.24E+13	6.91E+01	1.95E+01	8.60E+00	7.85E+02
2012 Kia Optima	UNI3	iBut16	3/5/2013										6.45	NA	NA	NA	NA	9.11E+01	2.36E+01	1.12E+01	9.79E+02
2012 Kia Optima	UNI1	iBut24	12/27/2012										6.53	5.23E+13	7.34E+12	4.06E+12	9.43E+12	7.16E+01	2.44E+01	6.51E+00	9.19E+02
2012 Kia Optima	UNI2	iBut24	12/28/2012										6.41	5.52E+13	7.28E+12	4.73E+12	9.56E+12	7.14E+01	2.51E+01	8.56E+00	9.50E+02
2012 Kia Optima	UNI3	iBut24	1/4/2013										6.98	5.55E+13	7.25E+12	3.94E+12	9.50E+12	3.58E+01	2.56E+01	5.50E+00	8.36E+02
2012 Kia Optima	UNI1	iBut32	2/21/2013										3.49	4.61E+13	3.73E+13	1.06E+12	3.53E+13	6.44E+01	9.30E+00	3.85E+00	4.71E+02
2012 Kia Optima	UNI2	iBut32	2/22/2013										2.56	4.04E+13	1.41E+13	8.48E+11	1.45E+13	NA	NA	NA	NA
2012 Kia Optima	UNI2	iBut32	2/25/2013										2.10	3.49E+13	1.37E+12	6.99E+11	3.06E+12	NA	NA	NA	NA
2012 Kia Optima	UNI1	E10/iBut8	10/9/2012										3.55	2.60E+13	6.32E+12	3.64E+12	7.16E+12	4.54E+01	1.94E+01	5.20E+00	6.90E+02
2012 Kia Optima	UNI2	E10/iBut8	10/10/2012										3.64	2.76E+13	6.05E+12	3.35E+12	6.98E+12	5.17E+01	1.63E+01	8.89E+00	6.39E+02
2012 Kia Optima	UNI3	E10/iBut8	10/11/2012										3.80	4.23E+13	5.78E+12	4.41E+12	7.58E+12	1.57E+01	1.88E+01	5.24E+00	5.75E+02

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	F Ew
2012 Chevrolet Impala	FTP1	E10	11/2/2012	0.022	0.002	0.004	0.006	0.019	0.001	0.001	0.005	0.004	0.001	0.003	0.002	0.133	0.312	0.039	0.200	0.040	0.000	0.000	0.008	406	421	332	394	21.0	20.3	25.7	21.7
2012 Chevrolet Impala	FTP2	E10	12/28/2012	0.027	0.002	0.002	0.007	0.023	0.002	0.001	0.006	0.005	0.000	0.001	0.001	0.152	0.196	0.000	0.133	0.041	0.001	0.003	0.010	431	426	331	401	19.8	20.1	25.8	21.3
2012 Chevrolet Impala	FTP3	E10	1/4/2013	0.024	0.004	0.000	0.007	0.020	0.002	0.000	0.005	0.004	0.001	0.001	0.002	0.159	0.202	0.021	0.144	0.036	0.001	0.000	0.008	406	424	336	396	21.0	20.2	25.4	21.6
2012 Chevrolet Impala	FTP1	E15	1/11/2013	0.032	0.002	0.001	0.008	0.028	0.002	0.000	0.007	0.005	0.000	0.001	0.002	0.158	0.198	0.008	0.137	0.047	0.000	0.001	0.010	428	430	338	404	19.5	19.4	24.7	20.7
2012 Chevrolet Impala	FTP2	E15	1/16/2013	0.031	0.002	0.002	0.008	0.026	0.002	0.001	0.007	0.006	0.000	0.001	0.002	0.196	0.138	0.012	0.115	0.044	0.001	0.001	0.010	443	434	343	411	18.8	19.2	24.3	20.3
2012 Chevrolet Impala	FTP3	E15	1/24/2013	0.029	0.004	0.003	0.009	0.026	0.003	0.001	0.007	0.004	0.001	0.003	0.002	0.134	0.297	0.048	0.194	0.038	0.000	0.000	0.008	407	422	334	395	20.5	19.8	25.0	21.2
2012 Chevrolet Impala	FTP1	E20	10/24/2012	0.036	0.003	0.001	0.009	0.033	0.001	0.000	0.007	0.004	0.002	0.001	0.002	0.125	0.265	0.029	0.171	0.055	0.000	0.001	0.012	398	418	327	389	20.5	19.5	25.0	21.0
2012 Chevrolet Impala	FTP2	E20	10/25/2012	0.024	0.002	0.002	0.007	0.021	0.002	0.001	0.005	0.004	0.001	0.001	0.002	0.113	0.268	0.004	0.163	0.040	0.001	0.001	0.009	403	426	325	394	20.3	19.2	25.2	20.8
2012 Chevrolet Impala	FTP3	E20	10/26/2012	0.025	0.003	0.003	0.008	0.021	0.002	0.001	0.006	0.005	0.001	0.001	0.002	0.091	0.281	0.000	0.164	0.040	0.000	0.001	0.009	404	424	332	394	20.2	19.3	24.6	20.7
2012 Chevrolet Impala	FTP1	iBut16	2/1/2013	0.020	0.002	0.002	0.006	0.017	0.002	0.001	0.005	0.004	0.000	0.001	0.001	0.122	0.205	0.025	0.138	0.044	0.000	0.002	0.010	418	427	334	400	20.6	20.2	25.9	21.6
2012 Chevrolet Impala	FTP2	iBut16	2/5/2013	0.030	0.003	0.002	0.008	0.025	0.002	0.001	0.007	0.006	0.001	0.002	0.002	0.160	0.181	0.024	0.133	0.036	0.000	0.001	0.008	408	429	327	396	21.2	20.1	26.4	21.8
2012 Chevrolet Impala	FTP3	iBut16	2/15/2013	0.059	0.000	0.000	0.012	0.055	0.000	0.000	0.012	0.004	0.000	0.002	0.001	0.135	0.216	0.007	0.142	0.047	0.001	0.002	0.011	405	427	337	398	21.3	20.2	25.6	21.7
2012 Chevrolet Impala	FTP1	iBut24	3/5/2013	0.022	0.003	0.006	0.008	0.019	0.001	0.003	0.005	0.004	0.002	0.004	0.003	0.129	0.213	0.052	0.151	0.053	0.000	0.001	0.011	406	413	324	387	20.8	20.4	26.0	21.8
2012 Chevrolet Impala	FTP2	iBut24	3/8/2013	0.030	0.002	0.002	0.008	0.025	0.001	0.001	0.006	0.006	0.001	0.002	0.002	0.170	0.296	0.007	0.190	0.035	0.000	0.001	0.008	404	420	326	391	20.8	20.0	25.8	21.6
2012 Chevrolet Impala	FTP3	iBut24	3/9/2013	0.024	0.002	0.001	0.006	0.018	0.000	0.000	0.004	0.007	0.002	0.002	0.003	0.156	0.207	0.006	0.141	0.041	0.001	0.002	0.010	414	418	320	390	20.4	20.2	26.4	21.6
2012 Chevrolet Impala	FTP1	iBut32	2/25/2013	0.025	0.004	0.004	0.008	0.021	0.003	0.002	0.006	0.005	0.002	0.002	0.002	0.132	0.262	0.039	0.174	0.054	0.000	0.000	0.012	399	424	326	392	20.7	19.5	25.3	21.1
2012 Chevrolet Impala	FTP2	iBut32	2/28/2013	0.026	0.003	0.003	0.007	0.022	0.002	0.001	0.006	0.005	0.001	0.002	0.002	0.094	0.200	0.023	0.129	0.052	0.001	0.001	0.012	434	429	332	403	19.1	19.3	24.9	20.5
2012 Chevrolet Impala	FTP3	iBut32	3/1/2013	0.022	0.003	0.003	0.007	0.018	0.002	0.001	0.005	0.005	0.001	0.002	0.002	0.136	0.186	0.011	0.127	0.050	0.000	0.001	0.011	402	417	329	390	20.6	19.8	25.2	21.2
2012 Chevrolet Impala	UNI1	E10	10/31/2012	0.068	0.002	0.004	0.005	0.060	0.001	0.001	0.004	0.008	0.000	0.003	0.001	0.295	0.132	0.000	0.131	0.116	0.002	0.006	0.008	708	365	529	394	12.1	23.4	16.2	21.7
2012 Chevrolet Impala	UNI2	E10	11/1/2012	0.084	0.002	0.004	0.007	0.075	0.001	0.000	0.005	0.011	0.001	0.004	0.002	0.278	0.138	0.005	0.136	0.113	0.001	0.003	0.007	723	364	535	394	11.8	23.5	16.0	21.7
2012 Chevrolet Impala	UNI3	E10	12/27/2012	0.078	0.003	0.004	0.007	0.068	0.003	0.001	0.006	0.012	0.000	0.004	0.001	0.455	0.173	0.008	0.176	0.112	0.001	0.001	0.007	765	358	548	392	11.2	23.8	15.6	21.8
2012 Chevrolet Impala	UNI1	E15	1/8/2013	0.076	0.000	0.022	0.006	0.071	0.001	0.012	0.005	0.005	0.000	0.012	0.001	0.527	0.105	0.000	0.119	0.116	0.002	0.004	0.008	788	360	543	394	10.6	23.2	15.4	21.2
2012 Chevrolet Impala	UNI2	E15	1/10/2013	0.090	0.003	0.004	0.007	0.078	0.002	0.002	0.006	0.013	0.000	0.002	0.001	0.268	0.164	0.000	0.158	0.104	0.004	0.006	0.010	730	364	543	395	11.4	22.9	15.4	21.1
2012 Chevrolet Impala	UNI3	E15	1/30/2013	0.080	0.003	0.008	0.007	0.071	0.002	0.003	0.006	0.010	0.000	0.005	0.001	0.283	0.131	0.000	0.130	0.123	0.002	0.011	0.009	718	362	529	392	11.6	23.1	15.8	21.3
2012 Chevrolet Impala	UNI1	E20	10/17/2012	0.067	0.002	0.000	0.005	0.057	0.002	0.000	0.005	0.011	0.000	0.000	0.001	0.335	0.075	0.018	0.084	0.100	0.003	0.006	0.008	713	365	548	395	11.5	22.4	14.9	20.7
2012 Chevrolet Impala	UNI2	E20	10/19/2012	0.093	0.003	0.003	0.008	0.084	0.002	0.000	0.006	0.011	0.001	0.004	0.002	0.297	0.127	0.002	0.127	0.112	0.000	0.004	0.006	715	360	537	391	11.4	22.7	15.2	20.9
2012 Chevrolet Impala	UNI3	E20	10/23/2012	0.063	0.002	0.009	0.006	0.052	0.001	0.003	0.004	0.012	0.001	0.006	0.002	0.351	0.120	0.000	0.123	0.111	0.001	0.004	0.007	738	368	539	399	11.1	22.2	15.2	20.5
2012 Chevrolet Impala	UNI1	iBut16	2/6/2013	0.092	0.002	0.005	0.007	0.080	0.002	0.001	0.006	0.014	0.001	0.004	0.002	0.340	0.048	0.001	0.060	0.127	0.002	0.005	0.008	752	360	543	392	11.5	24.0	15.9	22.0
2012 Chevrolet Impala	UNI2	iBut16	2/12/2013	0.061	0.002	0.005	0.005	0.050	0.002	0.002	0.004	0.013	0.000	0.003	0.001	0.391	0.097	0.004	0.106	0.111	0.002	0.006	0.008	769	367	542	400	11.2	23.5	15.9	21.6
2012 Chevrolet Impala	UNI3	iBut16	2/13/2013	0.074	0.002	0.004	0.006	0.063	0.002	0.002	0.005	0.013	0.000	0.002	0.001	0.450	0.149	0.016	0.155	0.101	0.003	0.008	0.008	738	359	542	391	11.7	24.0	15.9	22.1
2012 Chevrolet Impala	UNI1	iBut24	3/4/2013	0.071	0.003	0.005	0.006	0.061	0.002	0.001	0.005	0.012	0.001	0.004	0.002	0.330	0.119	0.000	0.122	0.121	0.004	0.003	0.010	717	352	530	383	11.7	23.9	15.9	22.0
2012 Chevrolet Impala	UNI2	iBut24	3/6/2013	0.089	0.003	0.005	0.007	0.075	0.002	0.001	0.005	0.016	0.001	0.004	0.002	0.455	0.098	0.006	0.110	0.109	0.003	0.009	0.009	719	349	532	381	11.7	24.1	15.9	22.1
2012 Chevrolet Impala	UNI3	iBut24	3/7/2013	0.102	0.001	0.009	0.007	0.089	0.000	0.006	0.005	0.015	0.001	0.004	0.002	0.310	0.175	0.016	0.171	0.119	0.002	0.005	0.008	763	360	529	393	11.0	23.4	15.9	21.5
2012 Chevrolet Impala	UNI1	iBut32	2/20/2013	0.082	0.002	0.004	0.006	0.071	0.002	0.002	0.005	0.013	0.000	0.003	0.001	0.559	0.114	0.000	0.130	0.102	0.001	0.002	0.006	801	368	537	402	10.3	22.5	15.4	20.6
2012 Chevrolet Impala	UNI2	iBut32	2/22/2013	0.085	0.002	0.005	0.006	0.075	0.002	0.001	0.005	0.012	0.000	0.004	0.001	0.376	0.162	0.013	0.163	0.105	0.003	0.005	0.009	742	359	526	390	11.1	23.0	15.7	21.2
2012 Chevrolet Impala	UNI3	iBut32	2/26/2013	0.106	0.004	0.005	0.009	0.092	0.003	0.002	0.007	0.017	0.001	0.004	0.002	0.476	0.150	0.015	0.158	0.134	0.003	0.019	0.011	742	361	532	393	11.1	22.9	15.5	21.1

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile				Black Carbon µg/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w	BC-1	BC-2	BC-3	BC-w
2012 Chevrolet Impala	FTP1	E10	11/2/2012	1.5	9.5	17.9	2.4	6.7	2.3	248.7	224.3	47.3	2.56	1.73E+13	1.39E+12	1.12E+12	4.60E+12	1.42E+03	6.36E+02	3.28E+02	7.15E+02
2012 Chevrolet Impala	FTP2	E10	12/28/2012	1.0	11.6	16.7	2.9	8.5	2.5	186.3	203.0	33.3	3.93	1.56E+13	1.55E+12	1.18E+12	4.36E+12	1.36E+03	9.51E+02	1.42E+02	8.14E+02
2012 Chevrolet Impala	FTP3	E10	1/4/2013	1.4	9.8	25.2	4.3	17.4	5.0	261.7	314.6	91.9	3.11	1.93E+13	1.34E+12	1.29E+12	5.06E+12	NA	NA	NA	NA
2012 Chevrolet Impala	FTP1	E15	1/11/2013	0.4	14.0	10.3	2.6	5.7	1.8	2.5	132.5	117.1	3.12	1.97E+13	7.40E+11	6.55E+11	4.67E+12	1.40E+03	2.38E+02	1.32E+02	4.50E+02
2012 Chevrolet Impala	FTP2	E15	1/16/2013	1.0	20.8	23.4	3.4	9.6	3.1	180.1	233.0	0.0	3.46	2.09E+13	9.34E+11	5.26E+11	4.97E+12	1.39E+03	1.69E+02	8.39E+01	4.01E+02
2012 Chevrolet Impala	FTP3	E15	1/24/2013	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.50E+13	6.44E+11	5.32E+11	3.61E+12	2.72E+03	4.37E+02	1.80E+02	5.38E+02
2012 Chevrolet Impala	FTP1	E20	10/24/2012	0.6	13.6	30.4	4.7	15.7	4.0	531.5	481.6	118.6	1.55	1.77E+13	1.40E+12	1.28E+12	4.75E+12	1.41E+03	2.62E+02	9.42E+01	4.55E+02
2012 Chevrolet Impala	FTP2	E20	10/25/2012	1.3	7.9	18.9	3.2	10.7	2.7	477.4	481.1	51.1	1.85	1.90E+13	1.57E+12	1.09E+12	5.07E+12	1.09E+03	5.50E+02	1.18E+02	5.43E+02
2012 Chevrolet Impala	FTP3	E20	10/26/2012	1.4	8.8	16.0	2.5	9.3	2.4	232.9	228.7	0.0	1.42	1.77E+13	1.34E+12	1.23E+12	4.71E+12	6.57E+02	5.96E+02	2.74E+02	5.20E+02
2012 Chevrolet Impala	FTP1	iBut16	2/1/2013	NA	NA	NA	NA	NA	NA	156.8	68.7	19.8	2.10	2.17E+13	7.47E+11	5.08E+11	5.05E+12	5.29E+03	3.52E+03	8.38E+02	8.50E+02
2012 Chevrolet Impala	FTP2	iBut16	2/5/2013	1.4	18.9	39.7	5.5	14.9	5.1	661.2	182.9	261.5	2.54	2.33E+13	6.28E+11	5.01E+11	5.32E+12	5.77E+03	3.38E+02	5.55E+02	4.26E+02
2012 Chevrolet Impala	FTP3	iBut16	2/15/2013	1.5	12.4	19.2	3.3	9.1	3.1	271.5	54.4	116.4	2.93	2.26E+13	1.22E+12	6.99E+11	5.52E+12	5.65E+03	4.87E+02	5.24E+02	4.36E+02
2012 Chevrolet Impala	FTP1	iBut24	3/5/2013	1.9	16.7	28.3	4.4	14.5	4.1	133.3	77.5	74.8	3.46	2.65E+13	2.45E+12	1.37E+12	7.16E+12	NA	NA	NA	NA
2012 Chevrolet Impala	FTP2	iBut24	3/8/2013	2.8	25.0	31.2	4.4	17.2	3.0	99.7	125.7	132.1	3.44	2.72E+13	3.41E+12	2.08E+12	8.01E+12	NA	NA	NA	NA
2012 Chevrolet Impala	FTP3	iBut24	3/9/2013	2.1	23.5	27.1	4.3	14.6	3.9	194.4	121.5	149.5	3.24	NA	NA	NA	NA	NA	NA	NA	NA
2012 Chevrolet Impala	FTP1	iBut32	2/25/2013	2.6	13.4	26.7	2.8	8.3	2.7	156.6	206.6	199.7	1.17	1.10E+13	1.23E+12	3.88E+11	3.02E+12	NA	NA	NA	NA
2012 Chevrolet Impala	FTP2	iBut32	2/28/2013	1.6	14.8	14.6	2.6	9.2	2.3	98.5	92.9	168.0	1.36	1.29E+13	7.45E+11	4.43E+11	3.20E+12	NA	NA	NA	NA
2012 Chevrolet Impala	FTP3	iBut32	3/1/2013	1.1	7.9	15.5	1.6	4.3	1.6	130.3	82.1	114.4	0.89	1.13E+13	1.41E+12	5.18E+11	3.23E+12	NA	NA	NA	NA
2012 Chevrolet Impala	UNI1	E10	10/31/2012										3.19	4.27E+13	3.60E+12	1.79E+12	5.46E+12	1.25E+03	4.56E+02	6.11E+02	5.07E+02
2012 Chevrolet Impala	UNI2	E10	11/1/2012										2.12	5.48E+13	4.53E+12	1.66E+12	6.91E+12	2.53E+03	6.04E+02	4.30E+02	6.91E+02
2012 Chevrolet Impala	UNI3	E10	12/27/2012										3.88	5.22E+13	3.81E+12	1.43E+12	6.11E+12	3.61E+03	3.85E+02	3.78E+02	5.50E+02
2012 Chevrolet Impala	UNI1	E15	1/8/2013										3.38	5.11E+13	3.09E+12	7.20E+11	5.39E+12	2.98E+03	4.74E+02	2.00E+02	5.84E+02
2012 Chevrolet Impala	UNI2	E15	1/10/2013										2.78	4.46E+13	2.74E+12	7.62E+11	4.75E+12	1.82E+03	5.99E+02	6.75E+02	6.67E+02
2012 Chevrolet Impala	UNI3	E15	1/30/2013										2.19	3.50E+13	2.22E+12	6.52E+11	3.82E+12	1.33E+03	9.65E+02	3.57E+02	8.74E+02
2012 Chevrolet Impala	UNI1	E20	10/17/2012										1.45	2.86E+13	3.53E+12	1.04E+12	4.66E+12	2.39E+03	3.60E+02	2.17E+02	4.55E+02
2012 Chevrolet Impala	UNI2	E20	10/19/2012										1.40	4.62E+13	3.90E+12	1.92E+12	5.95E+12	1.55E+03	4.63E+02	4.88E+02	5.21E+02
2012 Chevrolet Impala	UNI3	E20	10/23/2012										1.71	NA	NA	NA	NA	1.96E+03	5.01E+02	1.89E+02	5.55E+02
2012 Chevrolet Impala	UNI1	iBut16	2/6/2013										2.14	5.30E+13	2.58E+12	4.74E+11	5.03E+12	2.98E+03	4.74E+02	2.00E+02	5.84E+02
2012 Chevrolet Impala	UNI2	iBut16	2/12/2013										4.95	7.01E+13	3.80E+12	9.27E+11	7.04E+12	1.82E+03	5.99E+02	6.75E+02	6.67E+02
2012 Chevrolet Impala	UNI3	iBut16	2/13/2013										3.01	6.36E+13	2.89E+12	5.99E+11	5.84E+12	1.33E+03	9.65E+02	3.57E+02	8.74E+02
2012 Chevrolet Impala	UNI1	iBut24	3/4/2013										2.46	5.93E+13	5.13E+12	1.27E+12	7.67E+12	NA	NA	NA	NA
2012 Chevrolet Impala	UNI2	iBut24	3/6/2013										3.32	6.37E+13	6.36E+12	1.65E+12	9.00E+12	NA	NA	NA	NA
2012 Chevrolet Impala	UNI3	iBut24	3/7/2013										3.51	6.81E+13	6.15E+12	2.18E+12	9.15E+12	NA	NA	NA	NA
2012 Chevrolet Impala	UNI1	iBut32	2/20/2013										1.24	1.69E+13	1.46E+12	4.77E+11	2.19E+12	2.10E+03	3.28E+03	1.85E+02	4.41E+02
2012 Chevrolet Impala	UNI2	iBut32	2/22/2013										1.39	2.23E+13	1.86E+12	2.64E+11	2.82E+12	2.10E+03	2.60E+03	3.26E+02	3.82E+02
2012 Chevrolet Impala	UNI3	iBut32	2/26/2013										1.91	4.22E+13	3.37E+12	3.02E+11	5.17E+12	NA	NA	NA	NA

				g/mile																												mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2012 Mercedes-Benz E350 coupe	FTP1	E-10	4/26/2013	0.056	0.003	0.004	0.014	0.047	0.002	0.001	0.011	0.011	0.002	0.004	0.004	0.697	0.054	0.102	0.201	0.036	0.000	0.004	0.009	374	395	326	372	22.8	21.6	26.2	23.0
2012 Mercedes-Benz E350 coupe	FTP2	E-10	4/30/2013	0.058	0.002	0.006	0.015	0.048	0.002	0.003	0.011	0.012	0.001	0.003	0.004	0.660	0.043	0.131	0.196	0.035	0.002	0.001	0.009	388	396	329	376	21.9	21.6	26.0	22.7
2012 Mercedes-Benz E350 coupe	FTP3	E-10	5/1/2013	0.052	0.010	0.013	0.019	0.042	0.009	0.009	0.016	0.011	0.001	0.004	0.004	0.612	0.060	0.110	0.188	0.036	0.000	0.004	0.009	358	394	322	366	23.8	21.7	26.5	23.3
2012 Mercedes-Benz E350 coupe	FTP1	E15	7/23/2013	0.046	0.005	0.006	0.014	0.041	0.003	0.002	0.011	0.006	0.002	0.004	0.003	0.443	0.062	0.152	0.166	0.037	0.000	0.001	0.008	364	383	311	359	22.9	21.8	26.9	23.3
2012 Mercedes-Benz E350 coupe	FTP2	E15	7/24/2013	0.044	0.001	0.003	0.011	0.037	0.000	0.001	0.008	0.008	0.001	0.003	0.003	0.468	0.063	0.120	0.163	0.037	0.000	0.004	0.009	356	383	310	357	23.4	21.8	27.0	23.4
2012 Mercedes-Benz E350 coupe	FTP3	E15	7/26/2013	0.050	0.003	0.005	0.013	0.044	0.001	0.002	0.010	0.007	0.002	0.004	0.003	0.614	0.063	0.104	0.189	0.037	0.000	0.003	0.009	354	385	314	359	23.5	21.7	26.6	23.3
2012 Mercedes-Benz E350 coupe	FTP1	E-20	3/22/2013	0.038	0.006	0.010	0.014	0.034	0.006	0.007	0.012	0.005	0.000	0.003	0.002	0.381	0.058	0.093	0.135	0.033	0.000	0.003	0.008	352	381	312	356	23.2	21.5	26.2	23.0
2012 Mercedes-Benz E350 coupe	FTP2	E-20	3/26/2013	0.033	0.000	0.004	0.008	0.028	0.000	0.001	0.006	0.006	0.001	0.004	0.003	0.505	0.054	0.106	0.162	0.030	0.000	0.004	0.007	376	397	327	373	21.7	20.6	25.0	21.9
2012 Mercedes-Benz E350 coupe	FTP3	E-20	4/2/2013	0.030	0.000	0.004	0.008	0.026	0.000	0.001	0.006	0.005	0.000	0.004	0.002	0.563	0.047	0.078	0.163	0.032	0.000	0.005	0.008	361	382	327	363	22.6	21.4	25.0	22.5
2012 Mercedes-Benz E350 coupe	FTP1	iBut16	6/26/2013	0.040	0.001	0.003	0.010	0.036	0.001	0.001	0.008	0.005	0.000	0.002	0.002	0.451	0.036	0.068	0.131	0.036	0.001	0.003	0.009	364	389	315	364	23.7	22.2	27.4	23.7
2012 Mercedes-Benz E350 coupe	FTP2	iBut16	6/27/2013	0.040	0.002	0.004	0.010	0.036	0.001	0.001	0.009	0.004	0.000	0.003	0.002	0.424	0.053	0.084	0.139	0.040	0.000	0.003	0.009	369	393	317	367	23.4	22.0	27.2	23.5
2012 Mercedes-Benz E350 coupe	FTP3	iBut16	6/28/2013	0.034	0.001	0.003	0.008	0.030	0.000	0.001	0.007	0.005	0.000	0.002	0.002	0.415	0.041	0.089	0.132	0.035	0.000	0.003	0.008	364	392	320	367	23.7	22.0	27.0	23.6
2012 Mercedes-Benz E350 coupe	FTP1	iBut24	4/10/2013	0.064	0.001	0.004	0.015	0.060	0.002	0.002	0.014	0.005	0.000	0.003	0.002	0.561	0.048	0.125	0.176	0.026	0.000	0.004	0.007	373	389	342	372	22.6	21.7	24.7	22.6
2012 Mercedes-Benz E350 coupe	FTP2	iBut24	4/12/2013	0.045	0.000	0.004	0.010	0.040	0.000	0.001	0.009	0.005	0.000	0.003	0.002	0.578	0.046	0.111	0.174	0.034	0.000	0.003	0.008	362	389	326	366	23.2	21.7	25.8	23.0
2012 Mercedes-Benz E350 coupe	FTP3	iBut24	4/16/2013	0.051	0.002	0.005	0.013	0.045	0.002	0.002	0.011	0.007	0.000	0.003	0.002	0.653	0.055	0.160	0.208	0.034	0.000	0.005	0.008	383	392	328	373	21.9	21.5	25.7	22.6
2012 Mercedes-Benz E350 coupe	FTP1	iBut32	8/15/2013	0.030	0.002	0.004	0.009	0.026	0.001	0.001	0.006	0.006	0.001	0.004	0.003	0.328	0.043	0.100	0.118	0.031	0.000	0.004	0.008	357	388	313	361	23.2	21.3	26.4	22.9
2012 Mercedes-Benz E350 coupe	FTP2	iBut32	8/16/2013	0.035	0.002	0.005	0.010	0.030	0.001	0.001	0.007	0.005	0.001	0.004	0.003	0.353	0.053	0.076	0.122	0.036	0.000	0.005	0.009	357	389	316	362	23.2	21.3	26.2	22.8
2012 Mercedes-Benz E350 coupe	FTP3	iBut32	8/21/2013	0.035	0.006	0.004	0.011	0.031	0.005	0.000	0.009	0.005	0.000	0.004	0.002	0.466	0.056	0.066	0.144	0.036	0.000	0.005	0.009	356	386	313	360	23.2	21.4	26.4	23.0
2012 Mercedes-Benz E350 coupe	UNI1	E-10	6/12/2013	0.155	0.022	0.010	0.028	0.129	0.013	0.002	0.019	0.030	0.010	0.009	0.011	1.441	0.151	0.119	0.215	0.112	0.023	0.005	0.026	641	335	492	362	13.3	25.5	17.4	23.6
2012 Mercedes-Benz E350 coupe	UNI2	E-10	6/14/2013	0.122	0.009	0.006	0.015	0.111	0.009	0.003	0.014	0.012	0.001	0.004	0.001	1.164	0.210	0.127	0.254	0.105	0.012	0.004	0.016	636	342	504	368	13.4	25.0	16.9	23.2
2012 Mercedes-Benz E350 coupe	UNI3	E-10	6/16/2013	0.117	0.018	0.006	0.022	0.102	0.008	0.000	0.012	0.018	0.012	0.007	0.012	1.265	0.130	0.143	0.190	0.107	0.033	0.004	0.034	637	338	505	365	13.4	25.3	16.9	23.4
2012 Mercedes-Benz E350 coupe	UNI1	E15	8/1/2013	0.199	0.010	0.017	0.021	0.184	0.005	0.010	0.015	0.017	0.006	0.008	0.007	1.519	0.114	0.077	0.184	0.106	0.021	0.006	0.024	626	329	483	355	13.3	25.4	17.3	23.5
2012 Mercedes-Benz E350 coupe	UNI2	E15	8/6/2013	0.109	0.011	0.010	0.016	0.095	0.004	0.002	0.009	0.016	0.008	0.009	0.009	1.089	0.124	0.133	0.175	0.100	0.030	0.002	0.032	640	328	495	355	13.0	25.5	16.9	23.5
2012 Mercedes-Benz E350 coupe	UNI3	E15	8/7/2013	0.119	0.011	0.031	0.018	0.109	0.005	0.010	0.011	0.011	0.007	0.024	0.008	1.113	0.106	0.126	0.160	0.103	0.021	0.005	0.024	622	329	485	355	13.4	25.4	17.2	23.5
2012 Mercedes-Benz E350 coupe	UNI1	E-20	8/27/2013	0.117	0.006	0.012	0.012	0.101	0.001	0.003	0.007	0.018	0.005	0.010	0.006	1.609	0.110	0.119	0.188	0.096	0.020	0.013	0.024	610	325	481	351	13.3	25.1	17.0	23.3
2012 Mercedes-Benz E350 coupe	UNI2	E-20	8/28/2013	0.096	0.005	0.008	0.010	0.081	0.001	0.000	0.005	0.017	0.005	0.009	0.006	1.376	0.095	0.043	0.158	0.091	0.023	0.016	0.026	574	316	463	340	14.2	25.9	17.7	24.1
2012 Mercedes-Benz E350 coupe	UNI3	E-20	8/29/2013	0.087	0.011	0.013	0.015	0.077	0.005	0.005	0.009	0.012	0.007	0.009	0.007	0.843	0.162	0.066	0.191	0.097	0.030	0.021	0.033	579	320	472	344	14.1	25.6	17.3	23.8
2012 Mercedes-Benz E350 coupe	UNI1	iBut16	7/2/2013	0.142	0.007	0.020	0.015	0.127	0.005	0.014	0.012	0.018	0.002	0.007	0.003	1.267	0.115	0.047	0.170	0.099	0.006	0.009	0.011	629	339	504	365	13.7	25.5	17.2	23.6
2012 Mercedes-Benz E350 coupe	UNI2	iBut16	7/9/2013	0.134	0.013	0.022	0.020	0.120	0.010	0.018	0.017	0.016	0.003	0.005	0.004	1.310	0.130	0.085	0.188	0.108	0.005	0.010	0.011	644	335	502	363	13.4	25.8	17.2	23.8
2012 Mercedes-Benz E350 coupe	UNI3	iBut16	7/12/2013	0.104	0.009	0.006	0.013	0.091	0.004	0.000	0.008	0.015	0.006	0.007	0.006	1.358	0.123	0.071	0.183	0.102	0.014	0.006	0.018	654	334	495	361	13.2	25.9	17.4	23.9
2012 Mercedes-Benz E350 coupe	UNI1	iBut24	4/19/2013	0.130	0.008	0.007	0.014	0.118	0.002	0.001	0.008	0.014	0.007	0.008	0.007	1.481	0.147	0.081	0.212	0.085	0.017	0.015	0.021	622	335	492	361	13.5	25.1	17.1	23.4
2012 Mercedes-Benz E350 coupe	UNI2	iBut24	4/23/2013	0.131	0.005	0.009	0.012	0.116	0.003	0.002	0.009	0.018	0.003	0.008	0.004	1.313	0.133	0.165	0.196	0.106	0.008	0.005	0.013	682	345	513	374	12.3	24.4	16.4	22.5
2012 Mercedes-Benz E350 coupe	UNI3	iBut24	4/24/2013	0.225	0.011	0.010	0.022	0.207	0.006	0.002	0.016	0.021	0.005	0.008	0.006	1.696	0.153	0.070	0.226	0.101	0.006	0.013	0.011	720	341	512	372	11.7	24.7	16.5	22.6
2012 Mercedes-Benz E350 coupe	UNI1	iBut32	8/8/2013	0.121	0.011	0.010	0.017	0.099	0.003	0.001	0.008	0.025	0.010	0.011	0.010	1.505	0.094	0.063	0.166	0.098	0.017	0.021	0.022	618	329	489	355	13.3	25.1	16.9	23.3
2012 Mercedes-Benz E350 coupe	UNI2	iBut32	8/9/2013	0.105	0.006	0.010	0.012	0.091	0.003	0.001	0.008	0.017	0.004	0.010	0.005	1.031	0.106	0.083	0.153	0.106	0.006	0.022	0.013	633	328	489	355	13.0	25.2	16.9	23.3
2012 Mercedes-Benz E350 coupe	UNI3	iBut32	8/23/2013	0.096	0.011	0.010	0.015	0.083	0.005	0.002	0.009	0.015	0.006	0.010	0.007	1.153	0.137	0.105	0.187	0.083	0.017	0.016	0.021	602	324	483	349	13.7	25.5	17.1	23.7

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w
2012 Mercedes-Benz E350 coupe	FTP1	E-10	4/26/2013	3.2	86.4	62.3	7.9	29.0	9.9	208.6	167.9	54.2	0.14	8.05E+12	5.11E+10	3.69E+11	1.80E+12
2012 Mercedes-Benz E350 coupe	FTP2	E-10	4/30/2013	3.2	58.0	66.2	9.8	33.1	11.0	214.5	137.3	43.1	0.09	6.91E+12	3.90E+10	2.81E+11	1.53E+12
2012 Mercedes-Benz E350 coupe	FTP3	E-10	5/1/2013	1.5	52.7	59.1	9.5	32.0	10.2	244.2	163.2	71.6	0.04	4.37E+12	7.04E+10	2.05E+11	1.00E+12
2012 Mercedes-Benz E350 coupe	FTP1	E15	7/23/2013	1.1	18.9	60.4	11.1	27.4	8.2	274.3	253.9	58.8	0.53	7.51E+12	5.43E+10	2.63E+11	1.66E+12
2012 Mercedes-Benz E350 coupe	FTP2	E15	7/24/2013	2.4	18.4	48.9	7.8	20.4	6.6	237.9	288.8	44.4	0.38	6.82E+12	4.13E+10	2.42E+11	1.51E+12
2012 Mercedes-Benz E350 coupe	FTP3	E15	7/26/2013	1.0	50.2	87.2	18.1	44.5	13.3	328.5	508.3	74.4	0.23	6.24E+12	4.79E+10	1.33E+11	1.36E+12
2012 Mercedes-Benz E350 coupe	FTP1	E-20	3/22/2013	2.9	22.6	40.8	7.3	31.1	9.4	262.4	379.1	15.7	0.13	7.66E+12	4.50E+10	2.59E+11	1.70E+12
2012 Mercedes-Benz E350 coupe	FTP2	E-20	3/26/2013	1.8	23.1	38.3	6.3	24.3	6.6	239.0	317.7	0.0	0.33	6.62E+12	3.18E+10	1.99E+11	1.45E+12
2012 Mercedes-Benz E350 coupe	FTP3	E-20	4/2/2013	1.9	21.1	34.7	5.9	22.6	6.2	155.3	235.8	13.6	0.55	6.30E+12	3.27E+10	1.96E+11	1.38E+12
2012 Mercedes-Benz E350 coupe	FTP1	iBut16	6/26/2013	3.3	32.9	93.0	17.5	43.8	13.2	109.5	72.6	101.4	0.21	7.13E+12	5.16E+10	2.86E+11	1.59E+12
2012 Mercedes-Benz E350 coupe	FTP2	iBut16	6/27/2013	4.8	32.7	94.6	17.1	40.8	13.3	122.0	95.7	56.1	0.36	7.59E+12	4.39E+10	3.31E+11	1.69E+12
2012 Mercedes-Benz E350 coupe	FTP3	iBut16	6/28/2013	3.0	26.9	86.2	15.0	35.2	10.4	72.0	66.3	55.3	0.17	6.76E+12	4.40E+10	3.29E+11	1.51E+12
2012 Mercedes-Benz E350 coupe	FTP1	iBut24	4/10/2013	5.1	29.8	88.6	14.8	50.6	15.4	262.4	379.1	15.7	0.42	7.89E+12	5.58E+10	3.47E+11	1.76E+12
2012 Mercedes-Benz E350 coupe	FTP2	iBut24	4/12/2013	3.3	34.2	60.8	8.9	32.4	9.8	239.0	317.7	0.0	0.26	8.18E+12	6.48E+10	2.06E+11	1.79E+12
2012 Mercedes-Benz E350 coupe	FTP3	iBut24	4/16/2013	4.1	30.3	56.3	8.4	30.0	9.0	155.3	235.8	13.6	0.26	9.87E+12	3.85E+10	2.49E+11	2.14E+12
2012 Mercedes-Benz E350 coupe	FTP1	iBut32	8/15/2013	1.9	19.8	35.5	14.5	18.8	5.1	506.5	529.4	170.1	0.24	2.16E+13	3.20E+11	4.37E+11	1.34E+12
2012 Mercedes-Benz E350 coupe	FTP2	iBut32	8/16/2013	0.3	14.5	46.3	5.4	16.9	5.1	526.0	349.6	512.4	0.64	1.99E+13	2.84E+11	3.45E+11	1.23E+12
2012 Mercedes-Benz E350 coupe	FTP3	iBut32	8/21/2013	0.3	22.1	55.3	7.6	19.9	6.0	NA	NA	NA	0.72	NA	NA	NA	NA
2012 Mercedes-Benz E350 coupe	UNI1	E-10	6/12/2013										0.36	2.07E+13	8.55E+11	1.72E+11	1.84E+12
2012 Mercedes-Benz E350 coupe	UNI2	E-10	6/14/2013										0.34	1.94E+13	7.49E+11	2.15E+11	1.68E+12
2012 Mercedes-Benz E350 coupe	UNI3	E-10	6/16/2013										0.19	NA	NA	NA	NA
2012 Mercedes-Benz E350 coupe	UNI1	E15	8/1/2013										0.72	2.20E+13	9.51E+11	2.16E+11	1.99E+12
2012 Mercedes-Benz E350 coupe	UNI2	E15	8/6/2013										0.26	1.99E+13	1.50E+12	1.16E+11	2.36E+12
2012 Mercedes-Benz E350 coupe	UNI3	E15	8/7/2013										0.27	1.91E+13	5.66E+11	1.03E+11	1.50E+12
2012 Mercedes-Benz E350 coupe	UNI1	E-20	8/27/2013										0.60	1.88E+13	7.10E+11	1.98E+11	1.61E+12
2012 Mercedes-Benz E350 coupe	UNI2	E-20	8/28/2013										0.32	1.69E+13	6.43E+11	1.34E+11	1.45E+12
2012 Mercedes-Benz E350 coupe	UNI3	E-20	8/29/2013										0.42	1.73E+13	6.54E+11	1.18E+11	1.49E+12
2012 Mercedes-Benz E350 coupe	UNI1	iBut16	7/2/2013										NA	2.17E+13	7.97E+11	1.91E+11	1.85E+12
2012 Mercedes-Benz E350 coupe	UNI2	iBut16	7/9/2013										0.30	2.12E+13	8.07E+11	2.44E+11	1.82E+12
2012 Mercedes-Benz E350 coupe	UNI3	iBut16	7/12/2013										0.35	NA	NA	NA	NA
2012 Mercedes-Benz E350 coupe	UNI1	iBut24	4/19/2013										0.12	1.98E+13	8.50E+11	2.00E+11	1.79E+12
2012 Mercedes-Benz E350 coupe	UNI2	iBut24	4/23/2013										0.19	2.16E+13	7.34E+11	1.25E+11	1.77E+12
2012 Mercedes-Benz E350 coupe	UNI3	iBut24	4/24/2013										0.20	2.52E+13	7.51E+11	1.93E+11	1.97E+12
2012 Mercedes-Benz E350 coupe	UNI1	iBut32	8/8/2013										0.09	1.45E+13	3.43E+11	5.05E+10	1.06E+12
2012 Mercedes-Benz E350 coupe	UNI2	iBut32	8/9/2013										0.11	1.97E+13	2.92E+11	1.08E+11	1.29E+12
2012 Mercedes-Benz E350 coupe	UNI3	iBut32	8/23/2013										0.49	1.66E+13	1.51E+12	9.23E+10	2.19E+12

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2012 Mazda Mazda3	FTP1	E10	7/30/2013	0.039	0.001	0.003	0.009	0.032	0.001	0.001	0.007	0.009	0.000	0.002	0.002	1.662	0.348	0.390	0.632	0.007	0.008	0.006	0.007	296	279	242	272	28.7	30.6	35.2	31.3
2012 Mazda Mazda3	FTP2	E10	8/1/2013	0.033	0.001	0.004	0.008	0.028	0.001	0.001	0.006	0.006	0.000	0.003	0.002	1.082	0.334	0.464	0.525	0.015	0.011	0.007	0.011	282	282	239	270	30.1	30.3	35.7	31.5
2012 Mazda Mazda3	FTP3	E10	8/2/2013	0.039	0.002	0.003	0.010	0.032	0.001	0.001	0.007	0.009	0.001	0.003	0.003	1.257	0.303	0.492	0.554	0.006	0.009	0.005	0.007	286	275	241	268	29.7	31.0	35.4	31.8
2012 Mazda Mazda3	FTP1	E15	8/8/2013	0.033	0.001	0.001	0.008	0.029	0.001	0.000	0.006	0.005	0.000	0.002	0.002	1.076	0.193	0.316	0.410	0.008	0.007	0.007	0.007	291	277	238	269	28.5	30.1	35.1	31.0
2012 Mazda Mazda3	FTP2	E15	8/9/2013	0.030	0.008	0.003	0.011	0.024	0.008	0.000	0.009	0.008	0.000	0.004	0.002	0.995	0.215	0.563	0.472	0.009	0.007	0.006	0.007	282	266	235	261	29.5	31.4	35.5	32.0
2012 Mazda Mazda3	FTP3	E15	8/13/2013	0.047	0.001	0.004	0.011	0.039	0.001	0.001	0.009	0.009	0.000	0.004	0.003	1.205	0.241	0.427	0.493	0.011	0.005	0.006	0.006	288	276	238	268	28.8	30.2	34.9	31.1
2012 Mazda Mazda3	FTP1	E20	9/4/2013	0.031	0.003	0.005	0.009	0.027	0.002	0.001	0.007	0.005	0.001	0.005	0.003	0.587	0.117	0.213	0.241	0.011	0.013	0.008	0.011	233	249	188	229	35.0	32.9	43.5	35.7
2012 Mazda Mazda3	FTP2	E20	9/5/2013	0.034	0.000	0.003	0.008	0.028	0.000	0.000	0.006	0.007	0.000	0.005	0.003	0.990	0.293	0.307	0.442	0.008	0.006	0.005	0.006	278	269	234	261	29.2	30.3	34.9	31.2
2012 Mazda Mazda3	FTP3	E20	9/6/2013	0.035	0.000	0.005	0.009	0.029	0.000	0.001	0.006	0.007	0.000	0.005	0.003	0.870	0.228	0.382	0.404	0.011	0.008	0.009	0.009	272	261	232	256	29.9	31.2	35.1	31.9
2012 Mazda Mazda3	FTP1	iBut16	8/22/2013	0.029	0.002	0.006	0.009	0.025	0.002	0.002	0.007	0.005	0.000	0.004	0.002	0.900	0.145	0.388	0.369	0.014	0.016	0.007	0.013	276	272	235	263	31.1	31.7	36.7	32.8
2012 Mazda Mazda3	FTP2	iBut16	8/23/2013	0.032	0.002	0.005	0.009	0.028	0.002	0.001	0.007	0.005	0.000	0.004	0.002	1.211	0.339	0.335	0.519	0.011	0.006	0.008	0.008	283	271	235	263	30.3	31.9	36.7	32.7
2012 Mazda Mazda3	FTP3	iBut16	8/27/2013	0.032	0.003	0.006	0.010	0.028	0.002	0.002	0.007	0.005	0.000	0.005	0.002	1.019	0.217	0.308	0.409	0.014	0.009	0.008	0.010	287	284	240	273	29.9	30.4	35.9	31.6
2012 Mazda Mazda3	FTP1	iBut24	4/11/2013	0.055	0.001	0.005	0.013	0.046	0.002	0.002	0.011	0.010	0.000	0.003	0.003	1.388	0.339	0.496	0.600	0.005	0.007	0.007	0.006	284	270	238	264	29.5	31.2	35.3	31.8
2012 Mazda Mazda3	FTP2	iBut24	4/18/2013	0.025	0.002	0.003	0.007	0.023	0.002	0.002	0.006	0.002	0.000	0.001	0.001	0.685	0.362	0.250	0.399	0.011	0.007	0.006	0.007	285	272	238	266	29.4	30.9	35.4	31.7
2012 Mazda Mazda3	FTP3	iBut24	4/19/2013	0.038	0.002	0.003	0.010	0.032	0.002	0.001	0.008	0.006	0.000	0.002	0.002	0.867	0.370	0.230	0.435	0.007	0.007	0.004	0.006	280	273	238	265	30.0	30.8	35.4	31.7
2012 Mazda Mazda3	FTP1	iBut32	4/3/2013	0.033	0.000	0.003	0.008	0.029	0.000	0.000	0.006	0.005	0.000	0.003	0.002	0.792	0.174	0.234	0.319	0.011	0.010	0.015	0.012	281	268	241	263	29.2	30.8	34.3	31.3
2012 Mazda Mazda3	FTP2	iBut32	4/4/2013	0.034	0.012	0.015	0.017	0.029	0.013	0.012	0.016	0.007	0.000	0.003	0.002	0.664	0.224	0.220	0.314	0.005	0.005	0.009	0.006	291	274	241	268	28.3	30.2	34.2	30.8
2012 Mazda Mazda3	FTP3	iBut32	4/9/2013	0.039	0.001	0.004	0.010	0.033	0.003	0.002	0.009	0.006	0.000	0.002	0.002	0.668	0.155	0.290	0.299	0.015	0.009	0.010	0.010	282	265	238	261	29.2	31.2	34.7	31.6
2012 Mazda Mazda3	UNI1	E10	7/24/2013	0.083	0.002	0.001	0.006	0.074	0.002	0.000	0.006	0.010	0.000	0.003	0.001	0.956	0.756	0.148	0.724	0.054	0.006	0.014	0.009	477	276	365	293	17.9	30.8	23.4	29.1
2012 Mazda Mazda3	UNI2	E10	7/25/2013	0.080	0.001	0.001	0.005	0.072	0.002	0.000	0.005	0.010	0.000	0.004	0.001	1.119	0.678	0.092	0.661	0.043	0.012	0.024	0.014	474	277	356	292	18.0	30.8	24.0	29.1
2012 Mazda Mazda3	UNI3	E10	7/26/2013	0.088	0.007	0.007	0.011	0.079	0.007	0.004	0.011	0.011	0.000	0.004	0.001	1.027	0.491	0.044	0.487	0.045	0.007	0.027	0.011	473	270	359	287	18.0	31.6	23.8	29.7
2012 Mazda Mazda3	UNI1	E15	8/6/2013	0.101	0.004	0.007	0.009	0.085	0.004	0.004	0.008	0.018	0.000	0.003	0.001	1.720	1.145	0.439	1.126	0.021	0.008	0.011	0.009	477	268	357	285	17.4	31.0	23.3	29.1
2012 Mazda Mazda3	UNI2	E15	8/7/2013	0.098	0.003	0.003	0.007	0.082	0.002	0.001	0.006	0.018	0.001	0.002	0.002	1.897	1.080	0.080	1.054	0.022	0.008	0.022	0.009	474	266	365	283	17.5	31.2	22.9	29.3
2012 Mazda Mazda3	UNI3	E15	8/14/2013	0.115	0.003	0.004	0.009	0.096	0.002	0.001	0.007	0.021	0.001	0.004	0.002	2.437	1.035	0.476	1.068	0.022	0.007	0.011	0.008	485	270	372	288	17.1	30.8	22.4	28.8
2012 Mazda Mazda3	UNI1	E20	8/28/2013	0.080	0.002	0.004	0.006	0.070	0.001	0.000	0.005	0.012	0.001	0.004	0.002	1.577	0.703	0.336	0.723	0.045	0.012	0.030	0.015	450	258	344	273	18.0	31.6	23.8	29.8
2012 Mazda Mazda3	UNI2	E20	8/29/2013	0.081	0.004	0.011	0.008	0.069	0.003	0.007	0.007	0.014	0.001	0.005	0.001	0.887	0.577	0.262	0.576	0.037	0.010	0.034	0.013	461	263	407	281	17.7	31.0	20.1	29.0
2012 Mazda Mazda3	UNI3	E20	8/30/2013	0.092	0.005	0.012	0.010	0.078	0.005	0.003	0.009	0.017	0.000	0.009	0.002	1.359	0.896	0.218	0.873	0.013	0.010	0.020	0.011	453	265	342	280	18.0	30.7	23.9	29.1
2012 Mazda Mazda3	UNI1	iBut16	8/15/2013	0.114	0.006	0.007	0.011	0.098	0.005	0.003	0.009	0.019	0.001	0.005	0.002	2.828	1.265	0.516	1.293	0.014	0.011	0.015	0.012	470	269	352	285	18.2	31.9	24.5	30.1
2012 Mazda Mazda3	UNI2	iBut16	8/16/2013	0.091	0.002	0.005	0.007	0.079	0.002	0.001	0.006	0.014	0.001	0.005	0.002	2.294	0.960	0.325	0.985	0.033	0.006	0.015	0.008	471	268	363	285	18.2	32.1	23.8	30.2
2012 Mazda Mazda3	UNI3	iBut16	8/20/2013	0.090	0.002	0.006	0.007	0.078	0.002	0.001	0.006	0.013	0.001	0.006	0.002	1.938	1.006	0.740	1.035	0.041	0.008	0.018	0.011	466	270	355	286	18.4	31.8	24.2	30.1
2012 Mazda Mazda3	UNI1	iBut24	4/12/2013	0.108	0.002	0.003	0.007	0.092	0.001	0.001	0.006	0.018	0.000	0.003	0.001	2.515	0.923	0.725	0.991	0.031	0.010	0.012	0.011	483	270	361	287	17.3	31.0	23.3	29.2
2012 Mazda Mazda3	UNI2	iBut24	4/16/2013	0.134	0.002	0.005	0.009	0.114	0.002	0.001	0.007	0.023	0.000	0.004	0.002	2.132	0.723	0.403	0.774	0.017	0.009	0.016	0.010	475	275	355	291	17.6	30.5	23.7	28.9
2012 Mazda Mazda3	UNI3	iBut24	4/17/2013	0.104	0.002	0.003	0.007	0.091	0.003	0.001	0.007	0.014	0.000	0.002	0.001	1.837	0.808	0.401	0.833	0.033	0.007	0.013	0.008	483	276	365	292	17.4	30.5	23.1	28.7
2012 Mazda Mazda3	UNI1	iBut32	3/28/2013	0.106	0.001	0.001	0.006	0.090	0.000	0.000	0.005	0.018	0.000	0.002	0.001	1.198	0.465	0.140	0.481	0.067	0.014	0.024	0.017	479	269	352	286	17.2	30.7	23.5	28.9
2012 Mazda Mazda3	UNI2	iBut32	4/2/2013	0.143	0.001	0.002	0.008	0.119	0.000	0.000	0.007	0.028	0.000	0.004	0.002	2.230	0.662	0.208	0.713	0.015	0.015	0.012	0.015	463	269	353	285	17.7	30.6	23.4	28.9
2012 Mazda Mazda3	UNI3	iBut32	4/10/2013	0.116	0.010	0.032	0.017	0.100	0.009	0.028	0.015	0.019	0.000	0.005	0.002	1.819	0.704	0.210	0.727	0.027	0.010	0.028	0.012	465	268	343	283	17.7	30.8	24.1	29.1

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w
2012 Mazda Mazda3	FTP1	E10	7/30/2013	1.5	44.8	70.6	14.1	34.5	9.8	266.5	189.2	155.0	2.71	NA	NA	NA	NA
2012 Mazda Mazda3	FTP2	E10	8/1/2013	2.7	62.4	51.5	9.4	23.9	6.7	247.2	200.0	59.5	2.84	1.90E+13	5.54E+12	3.44E+12	7.76E+12
2012 Mazda Mazda3	FTP3	E10	8/2/2013	2.8	25.0	17.1	4.4	13.0	4.1	193.9	162.5	97.8	2.68	1.97E+13	6.66E+12	3.42E+12	8.48E+12
2012 Mazda Mazda3	FTP1	E15	8/8/2013	1.0	22.6	35.9	6.4	17.1	5.3	192.7	214.6	174.0	1.71	1.63E+13	3.98E+12	2.36E+12	6.08E+12
2012 Mazda Mazda3	FTP2	E15	8/9/2013	1.4	22.6	47.2	7.2	19.0	6.2	203.5	177.4	106.4	1.99	2.05E+13	5.97E+12	3.71E+12	8.36E+12
2012 Mazda Mazda3	FTP3	E15	8/13/2013	1.2	36.4	73.2	14.4	32.1	11.1	152.4	196.9	100.3	2.07	1.91E+13	3.83E+12	2.78E+12	6.72E+12
2012 Mazda Mazda3	FTP1	E20	9/4/2013	0.5	25.7	48.0	10.1	27.8	7.3	266.9	287.0	68.6	1.17	7.80E+12	8.66E+11	7.19E+11	2.26E+12
2012 Mazda Mazda3	FTP2	E20	9/5/2013	2.3	47.3	62.7	15.3	40.7	11.5	284.7	300.1	74.5	1.43	7.24E+12	7.06E+11	7.66E+11	2.08E+12
2012 Mazda Mazda3	FTP3	E20	9/6/2013	0.6	37.6	53.1	11.1	31.7	8.3	240.0	308.2	41.1	1.08	8.02E+12	8.74E+11	9.22E+11	2.37E+12
2012 Mazda Mazda3	FTP1	iBut16	8/22/2013	1.6	30.3	40.8	6.4	18.5	5.0	482.8	320.2	301.7	1.99	1.09E+13	1.96E+12	1.41E+12	3.67E+12
2012 Mazda Mazda3	FTP2	iBut16	8/23/2013	2.0	34.2	40.2	6.1	17.7	5.4	391.0	324.4	129.3	2.02	1.14E+13	1.55E+12	1.62E+12	3.60E+12
2012 Mazda Mazda3	FTP3	iBut16	8/27/2013	2.3	5.5	36.3	28.2	13.8	14.3	452.3	358.1	328.6	1.84	8.55E+12	1.53E+12	1.06E+12	2.86E+12
2012 Mazda Mazda3	FTP1	iBut24	4/11/2013	5.3	63.6	72.3	12.7	38.8	11.5	115.4	49.2	99.3	2.52	1.85E+13	3.77E+12	2.64E+12	6.52E+12
2012 Mazda Mazda3	FTP2	iBut24	4/18/2013	1.8	17.8	30.4	5.9	15.5	5.5	116.1	164.1	122.2	1.93	1.61E+13	3.34E+12	2.08E+12	5.64E+12
2012 Mazda Mazda3	FTP3	iBut24	4/19/2013	3.2	66.4	57.9	10.3	28.9	8.7	NA	NA	NA	2.31	NA	NA	NA	NA
2012 Mazda Mazda3	FTP1	iBut32	4/3/2013	4.8	27.1	68.8	7.4	22.3	5.8	214.3	152.1	147.3	0.59	2.62E+13	1.33E+12	1.87E+12	1.85E+12
2012 Mazda Mazda3	FTP2	iBut32	4/4/2013	4.2	26.6	61.4	6.8	17.3	5.5	132.8	63.5	181.5	0.50	2.74E+13	8.48E+11	1.02E+12	1.79E+12
2012 Mazda Mazda3	FTP3	iBut32	4/9/2013	4.3	39.5	57.0	6.6	17.1	4.8	168.8	80.3	200.6	1.91	3.18E+13	7.39E+11	1.09E+12	2.04E+12
2012 Mazda Mazda3	UNI1	E10	7/24/2013										2.84	4.21E+13	3.79E+12	2.55E+12	5.71E+12
2012 Mazda Mazda3	UNI2	E10	7/25/2013										2.29	4.40E+13	5.13E+12	3.13E+12	7.00E+12
2012 Mazda Mazda3	UNI3	E10	7/26/2013										2.48	4.08E+13	4.76E+12	3.23E+12	6.51E+12
2012 Mazda Mazda3	UNI1	E15	8/6/2013										3.07	3.86E+13	4.61E+12	3.39E+12	6.28E+12
2012 Mazda Mazda3	UNI2	E15	8/7/2013										1.73	3.90E+13	4.16E+12	4.71E+12	6.00E+12
2012 Mazda Mazda3	UNI3	E15	8/14/2013										1.21	4.18E+13	3.51E+12	3.03E+12	5.44E+12
2012 Mazda Mazda3	UNI1	E20	8/28/2013										0.70	1.99E+13	1.32E+12	2.86E+12	2.38E+12
2012 Mazda Mazda3	UNI2	E20	8/29/2013										0.78	2.12E+13	1.23E+12	2.04E+12	2.30E+12
2012 Mazda Mazda3	UNI3	E20	8/30/2013										0.57	NA	NA	NA	NA
2012 Mazda Mazda3	UNI1	iBut16	8/15/2013										1.16	4.07E+13	2.47E+12	3.84E+12	4.53E+12
2012 Mazda Mazda3	UNI2	iBut16	8/16/2013										1.48	3.69E+13	2.41E+12	2.01E+12	4.16E+12
2012 Mazda Mazda3	UNI3	iBut16	8/20/2013										0.97	3.47E+13	2.42E+12	2.38E+12	4.08E+12
2012 Mazda Mazda3	UNI1	iBut24	4/12/2013										2.05	5.06E+13	3.55E+12	2.57E+12	5.90E+12
2012 Mazda Mazda3	UNI2	iBut24	4/16/2013										2.48	6.41E+13	2.88E+12	3.12E+12	6.03E+12
2012 Mazda Mazda3	UNI3	iBut24	4/17/2013										2.04	4.56E+13	3.69E+12	2.34E+12	5.76E+12
2012 Mazda Mazda3	UNI1	iBut32	3/28/2013										0.50	2.03E+13	3.16E+11	5.04E+11	1.36E+12
2012 Mazda Mazda3	UNI2	iBut32	4/2/2013										0.91	1.03E+13	6.85E+11	5.89E+11	1.18E+12
2012 Mazda Mazda3	UNI3	iBut32	4/10/2013										1.04	1.98E+13	3.88E+11	3.90E+11	1.39E+12

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2013 Ford F-150 FFV	FTP1	E10	8/28/2013	0.115	0.001	0.021	0.030	0.098	0.000	0.013	0.024	0.019	0.001	0.009	0.007	1.706	0.029	0.996	0.642	0.025	0.002	0.004	0.007	479	472	417	459	17.7	18.1	20.4	18.6
2013 Ford F-150 FFV	FTP2	E10	8/29/2013	0.127	0.003	0.032	0.037	0.109	0.001	0.026	0.030	0.021	0.002	0.007	0.007	2.094	0.018	1.052	0.732	0.029	0.004	0.008	0.010	479	473	414	458	17.7	18.1	20.6	18.6
2013 Ford F-150 FFV	FTP3	E10	8/30/2013	0.157	0.002	0.023	0.040	0.137	0.001	0.016	0.033	0.023	0.002	0.008	0.008	2.223	0.043	0.351	0.580	0.037	0.000	0.006	0.009	485	476	411	460	17.5	17.9	20.8	18.5
2013 Ford F-150 FFV	FTP1	E51	11/15/2013	0.139	0.006	0.015	0.036	0.111	0.005	0.006	0.027	0.032	0.001	0.010	0.010	1.788	0.020	0.174	0.429	0.020	0.007	0.007	0.010	466	466	399	447	15.5	15.6	18.2	16.3
2013 Ford F-150 FFV	FTP2	E51	11/21/2013	0.132	0.002	0.022	0.034	0.103	0.000	0.009	0.024	0.033	0.001	0.015	0.012	1.516	0.064	0.522	0.491	0.016	0.001	0.008	0.006	471	466	401	449	15.4	15.6	18.1	16.2
2013 Ford F-150 FFV	FTP3	E51	11/22/2013	0.170	0.002	0.015	0.040	0.135	0.001	0.006	0.030	0.041	0.001	0.011	0.012	1.803	0.087	0.320	0.507	0.019	0.001	0.004	0.006	470	467	409	452	15.4	15.6	17.8	16.1
2013 Ford F-150 FFV	FTP1	E83	9/18/2013	0.181	0.004	0.020	0.045	0.115	0.001	0.004	0.026	0.077	0.003	0.019	0.023	1.426	0.151	0.323	0.464	0.016	0.001	0.008	0.006	478	478	413	460	12.9	13.0	15.0	13.5
2013 Ford F-150 FFV	FTP2	E83	9/19/2013	0.147	0.002	0.016	0.036	0.090	0.000	0.001	0.019	0.067	0.003	0.018	0.020	1.135	0.083	0.221	0.340	0.003	0.003	0.001	0.002	474	469	404	452	13.0	13.2	15.3	13.7
2013 Ford F-150 FFV	FTP3	E83	10/11/2013	0.200	0.002	0.020	0.048	0.126	0.000	0.003	0.027	0.086	0.002	0.020	0.024	1.502	0.104	0.350	0.462	0.015	0.000	0.004	0.004	486	480	421	465	12.7	12.9	14.7	13.3
2013 Ford F-150 FFV	FTP1	iBut55	10/30/2013	0.213	0.005	0.010	0.049	0.179	0.004	0.004	0.040	0.040	0.001	0.007	0.011	2.870	0.057	0.340	0.716	0.018	0.002	0.007	0.006	484	478	415	462	15.9	16.3	18.7	16.8
2013 Ford F-150 FFV	FTP2	iBut55	10/31/2013	0.184	0.004	0.010	0.043	0.154	0.003	0.005	0.035	0.035	0.001	0.006	0.009	2.599	0.123	0.305	0.688	0.017	0.001	0.004	0.005	485	482	423	466	15.9	16.2	18.4	16.7
2013 Ford F-150 FFV	FTP3	iBut55	11/1/2013	0.195	0.003	0.015	0.046	0.160	0.002	0.007	0.036	0.040	0.002	0.010	0.012	2.782	0.276	0.615	0.890	0.017	0.003	0.002	0.006	496	496	421	475	15.6	15.7	18.5	16.3
2013 Ford F-150 FFV	UNI1	E10	8/27/2013	0.474	0.004	0.037	0.031	0.409	0.003	0.023	0.026	0.075	0.001	0.016	0.006	5.472	0.202	0.581	0.499	0.058	0.006	0.017	0.010	826	465	621	494	10.2	18.4	13.8	17.3
2013 Ford F-150 FFV	UNI2	E10	9/4/2013	0.283	0.003	0.043	0.020	0.237	0.002	0.027	0.016	0.054	0.001	0.018	0.005	3.134	0.233	0.588	0.407	0.057	0.009	0.016	0.012	803	469	625	497	10.6	18.2	13.7	17.2
2013 Ford F-150 FFV	UNI3	E10	9/5/2013	0.156	0.020	0.009	0.026	0.122	0.018	0.000	0.022	0.040	0.002	0.015	0.005	2.295	0.248	0.319	0.359	0.059	0.007	0.010	0.010	777	473	623	499	10.9	18.0	13.7	17.1
2013 Ford F-150 FFV	UNI1	E51	11/5/2013	0.329	0.013	0.037	0.031	0.255	0.009	0.014	0.022	0.086	0.005	0.027	0.010	3.400	0.325	0.806	0.518	0.046	0.017	0.005	0.018	841	490	668	521	8.6	14.8	10.9	14.0
2013 Ford F-150 FFV	UNI2	E51	11/6/2013	0.355	0.007	0.031	0.026	0.271	0.004	0.009	0.018	0.096	0.003	0.025	0.009	3.969	0.264	0.198	0.450	0.035	0.008	0.013	0.009	823	482	667	512	8.8	15.1	10.9	14.2
2013 Ford F-150 FFV	UNI3	E51	11/7/2013	0.331	0.009	0.028	0.027	0.259	0.005	0.004	0.018	0.083	0.004	0.029	0.010	3.666	0.289	0.541	0.481	0.038	0.014	0.010	0.015	841	489	669	520	8.6	14.9	10.9	14.0
2013 Ford F-150 FFV	UNI1	E83	9/6/2013	0.265	0.006	0.030	0.021	0.182	0.004	0.003	0.013	0.096	0.003	0.031	0.010	1.282	0.072	0.517	0.165	0.040	0.004	0.000	0.005	781	461	658	491	7.9	13.4	9.4	12.6
2013 Ford F-150 FFV	UNI2	E83	9/12/2013	0.283	0.004	0.029	0.020	0.181	0.001	0.003	0.011	0.117	0.003	0.031	0.011	1.496	0.112	0.238	0.193	0.058	0.011	0.011	0.014	771	463	615	489	8.0	13.4	10.1	12.7
2013 Ford F-150 FFV	UNI3	E83	9/13/2013	0.239	0.003	0.033	0.017	0.144	0.001	0.003	0.009	0.110	0.002	0.035	0.010	2.337	0.053	0.233	0.184	0.026	0.007	0.010	0.008	775	451	597	477	8.0	13.8	10.4	13.0
2013 Ford F-150 FFV	UNI1	iBut55	10/16/2013	0.343	0.007	0.028	0.026	0.274	0.005	0.012	0.019	0.080	0.003	0.019	0.008	4.503	0.161	0.490	0.408	0.028	0.011	0.012	0.012	804	469	639	498	9.6	16.6	12.2	15.6
2013 Ford F-150 FFV	UNI2	iBut55	10/17/2013	0.459	0.005	0.030	0.030	0.379	0.003	0.013	0.023	0.093	0.003	0.020	0.008	5.673	0.159	0.964	0.500	0.031	0.008	0.006	0.009	787	470	654	499	9.8	16.6	11.9	15.6
2013 Ford F-150 FFV	UNI3	iBut55	10/25/2013	0.497	0.004	0.027	0.031	0.402	0.001	0.008	0.022	0.110	0.003	0.022	0.010	6.903	0.160	0.417	0.522	0.026	0.009	0.015	0.010	814	475	645	504	9.4	16.4	12.1	15.4

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w
2013 Ford F-150 FFV	FTP1	E10	8/28/2013	4.4	129.7	166.5	32.5	93.1	27.8	62.6	58.8	32.5	1.30	2.50E+12	1.11E+12	6.40E+11	1.27E+12
2013 Ford F-150 FFV	FTP2	E10	8/29/2013	0.5	54.5	85.1	18.3	45.5	12.5	53.2	34.6	35.9	0.59	2.79E+12	1.09E+12	6.30E+11	1.32E+12
2013 Ford F-150 FFV	FTP3	E10	8/30/2013	NA	189.4	179.5	NA	NA	NA	63.8	63.6	14.0	0.49	3.33E+12	1.71E+12	4.29E+11	1.69E+12
2013 Ford F-150 FFV	FTP1	E51	11/15/2013	6.0	105.8	130.6	39.7	44.8	16.1	66.1	234.1	38.9	1.63	6.96E+11	3.24E+11	1.14E+11	3.44E+11
2013 Ford F-150 FFV	FTP2	E51	11/21/2013	3.7	100.0	126.7	34.7	38.3	12.9	72.8	237.9	4.0	0.94	NA	NA	NA	NA
2013 Ford F-150 FFV	FTP3	E51	11/22/2013	8.9	NA	NA	42.9	47.2	18.1	39.6	267.4	16.6	1.13	8.94E+11	6.79E+11	9.43E+10	5.63E+11
2013 Ford F-150 FFV	FTP1	E83	9/18/2013	0.5	54.9	52.8	10.0	16.4	6.2	92.5	386.4	40.2	2.03	2.67E+12	1.15E+12	1.34E+11	1.19E+12
2013 Ford F-150 FFV	FTP2	E83	9/19/2013	1.7	44.9	56.0	9.1	18.1	7.2	67.2	224.9	19.7	2.15	1.88E+12	5.10E+11	9.50E+10	6.81E+11
2013 Ford F-150 FFV	FTP3	E83	10/11/2013	1.8	59.4	63.1	5.3	12.7	6.5	72.1	352.8	21.3	5.00	4.17E+11	3.57E+11	9.97E+10	2.99E+11
2013 Ford F-150 FFV	FTP1	iBut55	10/30/2013	9.9	104.2	38.3	12.5	36.2	10.5	102.5	67.7	100.9	1.05	2.56E+12	7.97E+11	1.52E+11	9.85E+11
2013 Ford F-150 FFV	FTP2	iBut55	10/31/2013	11.6	96.4	28.4	9.1	29.6	8.1	91.7	65.5	61.5	2.87	1.26E+12	4.02E+11	1.41E+11	5.07E+11
2013 Ford F-150 FFV	FTP3	iBut55	11/1/2013	15.8	102.9	27.4	11.6	32.6	9.2	109.5	70.1	131.7	2.16	8.53E+11	3.29E+11	9.75E+10	3.74E+11
2013 Ford F-150 FFV	UNI1	E10	8/27/2013										2.22	6.97E+12	1.71E+12	5.76E+11	1.91E+12
2013 Ford F-150 FFV	UNI2	E10	9/4/2013										1.01	5.04E+12	1.13E+12	2.94E+11	1.28E+12
2013 Ford F-150 FFV	UNI3	E10	9/5/2013										1.25	3.75E+12	1.30E+12	2.86E+11	1.35E+12
2013 Ford F-150 FFV	UNI1	E51	11/5/2013										1.14	4.57E+12	7.93E+11	9.22E+10	9.41E+11
2013 Ford F-150 FFV	UNI2	E51	11/6/2013										0.44	2.03E+12	2.36E+11	1.26E+11	3.20E+11
2013 Ford F-150 FFV	UNI3	E51	11/7/2013										0.60	NA	NA	NA	NA
2013 Ford F-150 FFV	UNI1	E83	9/6/2013										0.93	2.67E+12	1.15E+12	1.34E+11	1.19E+12
2013 Ford F-150 FFV	UNI2	E83	9/12/2013										0.85	1.88E+12	5.10E+11	9.50E+10	6.81E+11
2013 Ford F-150 FFV	UNI3	E83	9/13/2013										1.55	4.17E+11	3.57E+11	9.97E+10	2.99E+11
2013 Ford F-150 FFV	UNI1	iBut55	10/16/2013										1.16	3.61E+12	2.18E+12	1.81E+11	2.12E+12
2013 Ford F-150 FFV	UNI2	iBut55	10/17/2013										0.49	3.94E+12	2.80E+12	1.89E+11	2.68E+12
2013 Ford F-150 FFV	UNI3	iBut55	10/25/2013										0.75	5.68E+12	1.56E+12	2.38E+11	1.68E+12

				g/mile																								mpg			
Year/Make/Model	Test	Fuel Content	Date	THC1	THC2	THC3	THCw	NMHC1	NMHC2	NMHC3	NMHCw	CH41	CH42	CH43	CH4w	CO1	CO2	CO3	COw	NOx1	NOx2	NOx3	NOxw	CO21	CO22	CO23	CO2w	FE1	FE2	FE3	FEw
2014 Chevrolet Silverado	FTP1	E10	12/13/2013	0.252	0.006	0.006	0.057	0.217	0.005	0.001	0.048	0.041	0.001	0.006	0.011	2.110	0.144	0.134	0.550	0.014	0.005	0.006	0.007	571	544	473	530	16.1	16.0	15.8	15.7
2014 Chevrolet Silverado	FTP2	E10	12/16/2013	0.188	0.006	0.007	0.044	0.161	0.004	0.003	0.036	0.032	0.002	0.004	0.009	2.093	0.124	0.088	0.524	0.010	0.006	0.005	0.007	551	519	449	507	16.8	16.7	16.6	16.4
2014 Chevrolet Silverado	FTP3	E10	12/19/2013	0.211	0.003	0.006	0.047	0.181	0.001	0.002	0.039	0.034	0.002	0.005	0.009	1.893	0.120	0.091	0.480	0.008	0.006	0.004	0.006	540	529	452	510	16.7	16.6	16.4	16.3
2014 Chevrolet Silverado	FTP1	E51	11/14/2013	0.188	0.000	0.007	0.041	0.142	0.000	0.000	0.030	0.053	0.003	0.008	0.015	2.148	0.125	0.078	0.533	0.011	0.019	0.005	0.013	536	491	442	487	13.5	14.8	16.5	14.9
2014 Chevrolet Silverado	FTP2	E51	11/21/2013	0.165	0.003	0.008	0.038	0.119	0.001	0.000	0.025	0.053	0.003	0.010	0.015	1.517	0.126	0.173	0.429	0.010	0.009	0.008	0.009	532	521	451	504	13.6	14.0	16.1	14.4
2014 Chevrolet Silverado	FTP3	E51	11/22/2013	0.232	0.001	0.006	0.050	0.180	0.000	0.000	0.037	0.060	0.002	0.007	0.015	1.605	0.144	0.030	0.416	0.008	0.007	0.005	0.007	549	537	452	516	13.2	13.5	16.1	14.1
2014 Chevrolet Silverado	FTP1	E83	11/26/2013	0.237	0.009	0.012	0.057	0.155	0.006	0.001	0.035	0.095	0.003	0.013	0.025	1.623	0.115	0.071	0.415	0.009	0.009	0.005	0.008	556	506	436	497	11.1	12.2	14.2	12.5
2014 Chevrolet Silverado	FTP2	E83	11/27/2013	0.170	0.005	0.013	0.041	0.102	0.001	0.000	0.022	0.079	0.005	0.015	0.023	1.143	0.085	0.056	0.297	0.006	0.008	0.006	0.007	535	511	452	500	11.6	12.1	13.7	12.4
2014 Chevrolet Silverado	FTP3	E83	12/5/2013	0.188	0.005	0.011	0.044	0.118	0.001	0.001	0.025	0.081	0.004	0.012	0.022	1.021	0.067	0.020	0.252	0.011	0.011	0.007	0.010	524	505	434	489	11.8	12.3	14.3	12.7
2014 Chevrolet Silverado	FTP1	But55	12/6/2013	0.177	0.003	0.008	0.041	0.136	0.000	0.000	0.028	0.048	0.004	0.009	0.015	1.554	0.158	0.105	0.433	0.010	0.008	0.009	0.008	547	518	466	510	14.2	15.0	16.7	15.3
2014 Chevrolet Silverado	FTP2	But55	12/10/2013	0.108	0.002	0.005	0.025	0.080	0.001	0.001	0.017	0.032	0.001	0.006	0.009	0.985	0.170	0.136	0.330	0.008	0.004	0.005	0.005	548	516	448	504	14.2	15.1	17.4	15.4
2014 Chevrolet Silverado	FTP3	But55	12/11/2013	0.091	0.000	0.004	0.020	0.068	0.000	0.000	0.014	0.028	0.001	0.004	0.008	0.949	0.175	0.077	0.309	0.008	0.001	0.004	0.003	537	504	420	488	15.3	16.4	19.7	16.9
2014 Chevrolet Silverado	UNI1	E10	12/17/2013	0.491	0.004	0.015	0.030	0.415	0.002	0.000	0.023	0.089	0.002	0.019	0.008	4.219	0.302	0.427	0.513	0.020	0.007	0.013	0.008	998	560	743	595	14.3	14.2	14.1	14.0
2014 Chevrolet Silverado	UNI2	E10	12/18/2013	0.446	0.003	0.013	0.026	0.372	0.003	0.000	0.022	0.086	0.000	0.016	0.006	3.745	0.214	0.352	0.406	0.034	0.005	0.008	0.007	883	535	708	565	15.1	15.0	14.9	14.7
2014 Chevrolet Silverado	UNI3	E10	12/20/2013	0.449	0.004	0.017	0.028	0.370	0.003	0.000	0.022	0.091	0.001	0.022	0.007	3.796	0.250	0.335	0.437	0.022	0.004	0.007	0.005	905	519	691	550	15.5	15.4	15.3	15.1
2014 Chevrolet Silverado	UNI1	E51	11/15/2013	0.545	0.002	0.022	0.031	0.399	0.000	0.003	0.021	0.168	0.002	0.022	0.012	4.369	0.271	0.309	0.485	0.040	0.005	0.012	0.007	917	539	711	571	7.9	13.5	10.2	12.7
2014 Chevrolet Silverado	UNI2	E51	11/19/2013	0.428	0.008	0.031	0.031	0.299	0.003	0.004	0.018	0.149	0.006	0.031	0.015	3.262	0.273	0.386	0.433	0.027	0.003	0.009	0.005	893	543	713	573	8.1	13.4	10.2	12.7
2014 Chevrolet Silverado	UNI3	E51	11/20/2013	0.433	0.002	0.015	0.026	0.296	0.000	0.001	0.015	0.159	0.006	0.017	0.015	3.514	0.163	0.242	0.342	0.018	0.004	0.004	0.005	894	526	445	536	8.1	13.8	16.4	13.6
2014 Chevrolet Silverado	UNI1	E83	11/28/2013	0.585	0.007	0.041	0.039	0.356	0.000	0.003	0.018	0.266	0.010	0.044	0.026	2.130	0.204	0.251	0.306	0.028	0.006	0.018	0.008	913	521	714	555	6.8	11.9	8.7	11.2
2014 Chevrolet Silverado	UNI2	E83	11/29/2013	0.786	0.009	0.018	0.049	0.504	0.004	0.000	0.029	0.326	0.005	0.028	0.023	3.578	0.159	0.021	0.324	0.036	0.005	0.007	0.007	840	499	417	511	7.3	12.4	14.9	12.1
2014 Chevrolet Silverado	UNI3	E83	11/30/2013	0.492	0.006	0.030	0.033	0.258	0.001	0.000	0.015	0.270	0.005	0.036	0.021	2.087	0.108	0.200	0.217	0.036	0.006	0.016	0.008	856	497	715	531	7.2	12.5	8.7	11.7
2014 Chevrolet Silverado	UNI1	But55	12/7/2013	0.441	0.009	0.018	0.032	0.339	0.001	0.000	0.019	0.119	0.009	0.023	0.015	3.202	0.244	0.366	0.405	0.033	0.009	0.006	0.010	912	526	702	558	8.5	14.8	11.1	13.9
2014 Chevrolet Silverado	UNI2	But55	12/8/2013	0.459	0.006	0.013	0.030	0.348	0.001	0.000	0.019	0.128	0.005	0.016	0.012	3.061	0.212	0.202	0.358	0.035	0.005	0.011	0.007	907	516	720	550	8.5	15.1	10.8	14.1
2014 Chevrolet Silverado	UNI3	But55	12/9/2013	0.236	0.011	0.014	0.023	0.163	0.007	0.005	0.015	0.085	0.004	0.011	0.009	1.665	0.293	0.034	0.345	0.021	0.005	0.010	0.006	981	547	726	581	7.9	14.2	10.7	13.4

				1,3-Butadiene	Benzene	Toluene	Ethyl Benzene	m,p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde	Butyraldehyde	PM Mass	PN #/mile			
Year/Make/Model	Test	Fuel Content	Date	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(µg/mile)w	(mg/mile)w	PN-1	PN-2	PN-3	PN-w
2014 Chevrolet Silverado	FTP1	E10	12/13/2013	11.7	303.0	304.0	53.9	160.6	49.1	74.6	78.2	15.2	5.10	1.52E+13	2.52E+13	5.58E+12	1.77E+13
2014 Chevrolet Silverado	FTP2	E10	12/16/2013	11.5	236.7	261.1	51.1	135.9	40.4	61.6	57.4	23.4	4.59	1.87E+13	2.05E+13	3.64E+12	1.55E+13
2014 Chevrolet Silverado	FTP3	E10	12/19/2013	11.0	172.3	137.1	21.3	60.3	18.7	23.8	40.8	13.4	NA	1.62E+13	2.04E+13	2.17E+12	1.45E+13
2014 Chevrolet Silverado	FTP1	E51	11/14/2013	8.2	184.2	199.0	58.3	72.7	26.2	45.2	271.4	4.2	3.74	NA	NA	NA	NA
2014 Chevrolet Silverado	FTP2	E51	11/21/2013	7.5	87.5	90.4	25.4	33.9	11.7	51.2	234.8	15.0	1.60	1.17E+13	1.24E+13	2.99E+12	9.67E+12
2014 Chevrolet Silverado	FTP3	E51	11/22/2013	8.8	335.4	243.8	67.5	75.6	28.9	46.1	305.5	6.1	2.08	1.25E+13	1.31E+13	2.03E+12	9.92E+12
2014 Chevrolet Silverado	FTP1	E83	11/26/2013	11.0	105.9	79.5	9.8	22.2	9.6	87.8	529.9	26.9	NA	9.13E+12	8.71E+12	2.00E+12	6.95E+12
2014 Chevrolet Silverado	FTP2	E83	11/27/2013	3.6	73.7	43.2	4.1	7.4	4.1	49.6	395.4	11.9	1.62	7.46E+12	6.91E+12	2.04E+12	5.68E+12
2014 Chevrolet Silverado	FTP3	E83	12/5/2013	4.5	57.5	62.5	5.5	11.3	4.7	65.7	364.2	12.6	1.73	7.02E+11	8.13E+12	1.66E+12	4.81E+12
2014 Chevrolet Silverado	FTP1	But55	12/6/2013	12.9	102.8	29.5	7.8	21.7	6.4	77.5	48.0	25.6	4.79	1.42E+13	1.46E+13	2.43E+12	1.12E+13
2014 Chevrolet Silverado	FTP2	But55	12/10/2013	5.1	77.0	5.7	3.2	10.6	3.9	48.7	39.0	110.2	2.36	1.44E+13	1.46E+13	1.59E+12	1.10E+13
2014 Chevrolet Silverado	FTP3	But55	12/11/2013	12.8	69.2	14.2	4.8	18.0	4.0	57.1	43.7	75.4	1.88	1.36E+13	1.33E+13	1.84E+12	1.02E+13
2014 Chevrolet Silverado	UNI1	E10	12/17/2013										4.78	4.73E+13	4.47E+12	7.49E+12	6.86E+12
2014 Chevrolet Silverado	UNI2	E10	12/18/2013										4.18	4.07E+13	5.25E+12	4.92E+12	7.04E+12
2014 Chevrolet Silverado	UNI3	E10	12/20/2013										5.55	3.76E+13	4.61E+12	3.92E+12	6.26E+12
2014 Chevrolet Silverado	UNI1	E51	11/15/2013										2.30	2.07E+13	2.96E+12	3.70E+12	3.93E+12
2014 Chevrolet Silverado	UNI2	E51	11/19/2013										1.74	3.08E+13	3.67E+12	6.58E+12	5.26E+12
2014 Chevrolet Silverado	UNI3	E51	11/20/2013										0.91	2.25E+13	2.38E+12	3.31E+12	3.50E+12
2014 Chevrolet Silverado	UNI1	E83	11/28/2013										1.81	1.75E+13	2.58E+12	3.58E+12	3.41E+12
2014 Chevrolet Silverado	UNI2	E83	11/29/2013										0.91	1.92E+13	2.14E+12	6.57E+12	3.32E+12
2014 Chevrolet Silverado	UNI3	E83	11/30/2013										0.73	1.96E+13	1.76E+12	4.22E+12	2.86E+12
2014 Chevrolet Silverado	UNI1	But55	12/7/2013										1.60	NA	NA	NA	NA
2014 Chevrolet Silverado	UNI2	But55	12/8/2013										1.85	3.24E+13	2.04E+12	3.54E+12	3.71E+12
2014 Chevrolet Silverado	UNI3	But55	12/9/2013										3.05	3.88E+13	2.74E+12	5.37E+12	4.77E+12

APPENDIX B.
Statistical Analysis Summary

Table 1: Test the Significance of the Fixed Effect – Fuel Type for THC1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	4.22	0.0005
Test	1	221	1022.09	<.0001
Fuel2*Test	6	221	1.78	0.1045

Table 2: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-2.4718	0.084433
Fuel2	B		-2.3251	0.097774
Fuel2	C		-2.3986	0.090845
Fuel2	D		-2.4002	0.0907
Fuel2	E		-2.3409	0.096241
Fuel2	F		-2.3680	0.093668
Fuel2	G		-2.6551	0.070292
Test		**FTP**	-2.9421	0.052755
Test		**UNI**	-1.9035	0.149046

Table 3: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	**A**		**B**		-0.1467	0.04978	227	-2.95	0.0035	Tukey-Kramer	0.0539
Fuel2	**A**		**C**		-0.07323	0.04978	227	-1.47	0.1427	Tukey-Kramer	0.7617
Fuel2	**A**		**D**		-0.07160	0.04978	227	-1.44	0.1517	Tukey-Kramer	0.7804
Fuel2	**A**		**E**		-0.1310	0.05583	227	-2.35	0.0198	Tukey-Kramer	0.2270
Fuel2	**A**		**F**		-0.1038	0.05583	227	-1.86	0.0643	Tukey-Kramer	0.5096
Fuel2	**A**		**G**		0.1832	0.07866	227	2.33	0.0207	Tukey-Kramer	0.2346
Fuel2	**B**		**C**		0.07351	0.05007	227	1.47	0.1434	Tukey-Kramer	0.7633
Fuel2	**B**		**D**		0.07514	0.05007	227	1.50	0.1348	Tukey-Kramer	0.7441
Fuel2	**B**		**E**		0.01576	0.05596	227	0.28	0.7784	Tukey-Kramer	1.0000
Fuel2	**B**		**F**		0.04294	0.05596	227	0.77	0.4436	Tukey-Kramer	0.9878
Fuel2	**B**		**G**		0.3300	0.07875	227	4.19	<.0001	Tukey-Kramer	0.0008
Fuel2	**C**		**D**		0.001629	0.05007	227	0.03	0.9741	Tukey-Kramer	1.0000
Fuel2	**C**		**E**		-0.05775	0.05596	227	-1.03	0.3032	Tukey-Kramer	0.9461
Fuel2	**C**		**F**		-0.03057	0.05596	227	-0.55	0.5854	Tukey-Kramer	0.9981
Fuel2	**C**		**G**		0.2565	0.07875	227	3.26	0.0013	Tukey-Kramer	0.0218
Fuel2	**D**		**E**		-0.05938	0.05596	227	-1.06	0.2898	Tukey-Kramer	0.9386
Fuel2	**D**		**F**		-0.03220	0.05596	227	-0.58	0.5656	Tukey-Kramer	0.9974
Fuel2	**D**		**G**		0.2548	0.07875	227	3.24	0.0014	Tukey-Kramer	0.0232
Fuel2	**E**		**F**		0.02718	0.05924	227	0.46	0.6468	Tukey-Kramer	0.9993
Fuel2	**E**		**G**		0.3142	0.08111	227	3.87	0.0001	Tukey-Kramer	0.0026
Fuel2	**F**		**G**		0.2870	0.08111	227	3.54	0.0005	Tukey-Kramer	0.0087
Test		**FTP**		**UNI**	-1.0386	0.02956	227	-35.13	<.0001	Tukey-Kramer	<.0001

Table 4: Test the Significance of the Fixed Effect – Fuel Type for NMHC1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	3.92	0.0010
Test	1	221	924.66	<.0001
Fuel2*Test	6	221	1.76	0.1077

Table 5: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-2.6061	0.073822
Fuel2	B		-2.4504	0.086259
Fuel2	C		-2.5323	0.079476
Fuel2	D		-2.5253	0.080034
Fuel2	E		-2.4686	0.084703
Fuel2	F		-2.5071	0.081504
Fuel2	G		-2.7825	0.061884
Test		FTP	-3.0734	0.046264
Test		UNI	-2.0329	0.130955

Table 6: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		-0.1556	0.05236	227	-2.97	0.0033	Tukey-Kramer	0.0503
Fuel2	A		C		-0.07379	0.05236	227	-1.41	0.1601	Tukey-Kramer	0.7964
Fuel2	A		D		-0.08072	0.05236	227	-1.54	0.1245	Tukey-Kramer	0.7192
Fuel2	A		E		-0.1375	0.05872	227	-2.34	0.0201	Tukey-Kramer	0.2293
Fuel2	A		F		-0.09893	0.05872	227	-1.68	0.0934	Tukey-Kramer	0.6269
Fuel2	A		G		0.1765	0.08272	227	2.13	0.0340	Tukey-Kramer	0.3368
Fuel2	B		C		0.08184	0.05265	227	1.55	0.1215	Tukey-Kramer	0.7114
Fuel2	B		D		0.07491	0.05265	227	1.42	0.1562	Tukey-Kramer	0.7891
Fuel2	B		E		0.01818	0.05885	227	0.31	0.7577	Tukey-Kramer	0.9999
Fuel2	B		F		0.05671	0.05885	227	0.96	0.3362	Tukey-Kramer	0.9612
Fuel2	B		G		0.3321	0.08282	227	4.01	<.0001	Tukey-Kramer	0.0016
Fuel2	C		D		-0.00693	0.05265	227	-0.13	0.8954	Tukey-Kramer	1.0000
Fuel2	C		E		-0.06366	0.05885	227	-1.08	0.2805	Tukey-Kramer	0.9329
Fuel2	C		F		-0.02513	0.05885	227	-0.43	0.6697	Tukey-Kramer	0.9995
Fuel2	C		G		0.2503	0.08282	227	3.02	0.0028	Tukey-Kramer	0.0438
Fuel2	D		E		-0.05673	0.05885	227	-0.96	0.3361	Tukey-Kramer	0.9611
Fuel2	D		F		-0.01820	0.05885	227	-0.31	0.7574	Tukey-Kramer	0.9999
Fuel2	D		G		0.2572	0.08282	227	3.11	0.0021	Tukey-Kramer	0.0344
Fuel2	E		F		0.03853	0.06230	227	0.62	0.5369	Tukey-Kramer	0.9962
Fuel2	E		G		0.3139	0.08530	227	3.68	0.0003	Tukey-Kramer	0.0053
Fuel2	F		G		0.2754	0.08530	227	3.23	0.0014	Tukey-Kramer	0.0238
Test		FTP		UNI	-1.0405	0.03109	227	-33.47	<.0001	Tukey-Kramer	<.0001

Table 7: Test the Significance of the Fixed Effect – Fuel Type for CH41

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	3.58	0.0021
Test	1	221	845.02	<.0001
Fuel2*Test	6	221	1.64	0.1372

Table 8: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-4.4468	0.011716
Fuel2	B		-4.3656	0.012707
Fuel2	C		-4.3684	0.012671
Fuel2	D		-4.4371	0.01183
Fuel2	E		-4.3683	0.012673
Fuel2	F		-4.3093	0.013443
Fuel2	G		-4.6804	0.009275
Test		FTP	-4.9468	0.007106
Test		UNI	-3.9035	0.020171

Table 9: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		-0.08119	0.05549	227	-1.46	0.1448	Tukey-Kramer	0.7663
Fuel2	A		C		-0.07833	0.05549	227	-1.41	0.1595	Tukey-Kramer	0.7952
Fuel2	A		D		-0.00969	0.05549	227	-0.17	0.8616	Tukey-Kramer	1.0000
Fuel2	A		E		-0.07844	0.06223	227	-1.26	0.2088	Tukey-Kramer	0.8691
Fuel2	A		F		-0.1375	0.06223	227	-2.21	0.0282	Tukey-Kramer	0.2947
Fuel2	A		G		0.2336	0.08768	227	2.66	0.0083	Tukey-Kramer	0.1123
Fuel2	B		C		0.002861	0.05581	227	0.05	0.9592	Tukey-Kramer	1.0000
Fuel2	B		D		0.07151	0.05581	227	1.28	0.2014	Tukey-Kramer	0.8599
Fuel2	B		E		0.002750	0.06237	227	0.04	0.9649	Tukey-Kramer	1.0000
Fuel2	B		F		-0.05629	0.06237	227	-0.90	0.3678	Tukey-Kramer	0.9719
Fuel2	B		G		0.3148	0.08777	227	3.59	0.0004	Tukey-Kramer	0.0074
Fuel2	C		D		0.06865	0.05581	227	1.23	0.2199	Tukey-Kramer	0.8818
Fuel2	C		E		-0.00011	0.06237	227	-0.00	0.9986	Tukey-Kramer	1.0000
Fuel2	C		F		-0.05915	0.06237	227	-0.95	0.3440	Tukey-Kramer	0.9641
Fuel2	C		G		0.3119	0.08777	227	3.55	0.0005	Tukey-Kramer	0.0083
Fuel2	D		E		-0.06876	0.06237	227	-1.10	0.2715	Tukey-Kramer	0.9269
Fuel2	D		F		-0.1278	0.06237	227	-2.05	0.0416	Tukey-Kramer	0.3870
Fuel2	D		G		0.2433	0.08777	227	2.77	0.0060	Tukey-Kramer	0.0860
Fuel2	E		F		-0.05904	0.06603	227	-0.89	0.3722	Tukey-Kramer	0.9732
Fuel2	E		G		0.3120	0.09041	227	3.45	0.0007	Tukey-Kramer	0.0117
Fuel2	F		G		0.3711	0.09041	227	4.10	<.0001	Tukey-Kramer	0.0011
Test		FTP		UNI	-1.0433	0.03295	227	-31.66	<.0001	Tukey-Kramer	<.0001

Table 10: Test the Significance of the Fixed Effect – Fuel Type for Cow

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	2.40	0.0291
Test	1	221	39.09	<.0001
Fuel2*Test	6	221	0.17	0.9837

Table 11: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-1.5240	0.217839
Fuel2	B		-1.5971	0.202483
Fuel2	C		-1.6337	0.195206
Fuel2	D		-1.5964	0.202625
Fuel2	E		-1.4711	0.229673
Fuel2	F		-1.5717	0.207692
Fuel2	G		-1.7839	0.167982
Test		FTP	-1.7228	0.178565
Test		UNI	-1.4709	0.229719

Table 12: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.07309	0.05909	227	1.24	0.2174	Tukey-Kramer	0.8790
Fuel2	A		C		0.1097	0.05909	227	1.86	0.0646	Tukey-Kramer	0.5112
Fuel2	A		D		0.07237	0.05909	227	1.22	0.2219	Tukey-Kramer	0.8839
Fuel2	A		E		-0.05294	0.06626	227	-0.80	0.4252	Tukey-Kramer	0.9849
Fuel2	A		F		0.04763	0.06626	227	0.72	0.4730	Tukey-Kramer	0.9914
Fuel2	A		G		0.2598	0.09336	227	2.78	0.0058	Tukey-Kramer	0.0836
Fuel2	B		C		0.03662	0.05942	227	0.62	0.5383	Tukey-Kramer	0.9962
Fuel2	B		D		-0.00072	0.05942	227	-0.01	0.9903	Tukey-Kramer	1.0000
Fuel2	B		E		-0.1260	0.06641	227	-1.90	0.0590	Tukey-Kramer	0.4840
Fuel2	B		F		-0.02546	0.06641	227	-0.38	0.7018	Tukey-Kramer	0.9997
Fuel2	B		G		0.1867	0.09346	227	2.00	0.0469	Tukey-Kramer	0.4189
Fuel2	C		D		-0.03735	0.05942	227	-0.63	0.5303	Tukey-Kramer	0.9958
Fuel2	C		E		-0.1627	0.06641	227	-2.45	0.0151	Tukey-Kramer	0.1834
Fuel2	C		F		-0.06208	0.06641	227	-0.93	0.3509	Tukey-Kramer	0.9665
Fuel2	C		G		0.1501	0.09346	227	1.61	0.1097	Tukey-Kramer	0.6786
Fuel2	D		E		-0.1253	0.06641	227	-1.89	0.0605	Tukey-Kramer	0.4912
Fuel2	D		F		-0.02474	0.06641	227	-0.37	0.7099	Tukey-Kramer	0.9998
Fuel2	D		G		0.1874	0.09346	227	2.01	0.0461	Tukey-Kramer	0.4140

Table 13: Test the Significance of the Fixed Effect – Fuel Type for CO1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	1.82	0.0959
Test	1	221	324.56	<.0001
Fuel2*Test	6	221	2.93	0.0090

Table 14: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transfromed**
Fuel2*Test	A	FTP	-0.7560	0.469541
Fuel2*Test	A	UNI	-0.1279	0.879941
Fuel2*Test	B	FTP	-0.7849	0.456165
Fuel2*Test	B	UNI	0.02327	1.023543
Fuel2*Test	C	FTP	-0.8665	0.42042
Fuel2*Test	C	UNI	0.08993	1.094098
Fuel2*Test	D	FTP	-0.8118	0.444058
Fuel2*Test	D	UNI	0.03245	1.032982
Fuel2*Test	E	FTP	-0.7910	0.453391
Fuel2*Test	E	UNI	0.09588	1.100627
Fuel2*Test	F	FTP	-1.0243	0.359048
Fuel2*Test	F	UNI	0.08116	1.084544

Table 15: Differences of Least Squares Means (Test FTP)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	B	0.03324	0.07097	108	0.47	0.6404	Tukey-Kramer	0.9992
Fuel2	A	C	0.1148	0.07097	108	1.62	0.1088	Tukey-Kramer	0.6717
Fuel2	A	D	0.06013	0.07097	108	0.85	0.3987	Tukey-Kramer	0.9792
Fuel2	A	E	0.05627	0.07981	108	0.71	0.4823	Tukey-Kramer	0.9920
Fuel2	A	F	0.2896	0.07981	108	3.63	0.0004	Tukey-Kramer	0.0077
Fuel2	A	G	0.1290	0.1126	108	1.15	0.2545	Tukey-Kramer	0.9123
Fuel2	B	C	0.08151	0.07173	108	1.14	0.2583	Tukey-Kramer	0.9154
Fuel2	B	D	0.02689	0.07173	108	0.37	0.7085	Tukey-Kramer	0.9998
Fuel2	B	E	0.02303	0.08015	108	0.29	0.7744	Tukey-Kramer	1.0000
Fuel2	B	F	0.2564	0.08015	108	3.20	0.0018	Tukey-Kramer	0.0291
Fuel2	B	G	0.09571	0.1128	108	0.85	0.3981	Tukey-Kramer	0.9791
Fuel2	C	D	-0.05462	0.07173	108	-0.76	0.4481	Tukey-Kramer	0.9880
Fuel2	C	E	-0.05849	0.08015	108	-0.73	0.4672	Tukey-Kramer	0.9904
Fuel2	C	F	0.1749	0.08015	108	2.18	0.0313	Tukey-Kramer	0.3140
Fuel2	C	G	0.01420	0.1128	108	0.13	0.9001	Tukey-Kramer	1.0000
Fuel2	D	E	-0.00386	0.08015	108	-0.05	0.9616	Tukey-Kramer	1.0000
Fuel2	D	F	0.2295	0.08015	108	2.86	0.0050	Tukey-Kramer	0.0724
Fuel2	D	G	0.06882	0.1128	108	0.61	0.5431	Tukey-Kramer	0.9964
Fuel2	E	F	0.2334	0.08488	108	2.75	0.0070	Tukey-Kramer	0.0961
Fuel2	E	G	0.07268	0.1162	108	0.63	0.5330	Tukey-Kramer	0.9958

Table 16: Differences of Least Squares Means (Test UC)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	B	-0.1512	0.09231	107	-1.64	0.1044	Tukey-Kramer	0.6583
Fuel2	A	C	-0.2178	0.09231	107	-2.36	0.0201	Tukey-Kramer	0.2261
Fuel2	A	D	-0.1604	0.09231	107	-1.74	0.0852	Tukey-Kramer	0.5928
Fuel2	A	E	-0.2410	0.1032	107	-2.34	0.0214	Tukey-Kramer	0.2371
Fuel2	A	F	-0.2263	0.1032	107	-2.19	0.0305	Tukey-Kramer	0.3081
Fuel2	A	G	0.3405	0.1452	107	2.35	0.0209	Tukey-Kramer	0.2327
Fuel2	B	C	-0.06666	0.09231	107	-0.72	0.4717	Tukey-Kramer	0.9910
Fuel2	B	D	-0.00918	0.09231	107	-0.10	0.9209	Tukey-Kramer	1.0000
Fuel2	B	E	-0.08984	0.1032	107	-0.87	0.3859	Tukey-Kramer	0.9762
Fuel2	B	F	-0.07512	0.1032	107	-0.73	0.4683	Tukey-Kramer	0.9906
Fuel2	B	G	0.4917	0.1452	107	3.39	0.0010	Tukey-Kramer	0.0167
Fuel2	C	D	0.05748	0.09231	107	0.62	0.5348	Tukey-Kramer	0.9959
Fuel2	C	E	-0.02317	0.1032	107	-0.22	0.8228	Tukey-Kramer	1.0000
Fuel2	C	F	-0.00845	0.1032	107	-0.08	0.9349	Tukey-Kramer	1.0000
Fuel2	C	G	0.5584	0.1452	107	3.85	0.0002	Tukey-Kramer	0.0038
Fuel2	D	E	-0.08066	0.1032	107	-0.78	0.4362	Tukey-Kramer	0.9863
Fuel2	D	F	-0.06594	0.1032	107	-0.64	0.5242	Tukey-Kramer	0.9953
Fuel2	D	G	0.5009	0.1452	107	3.45	0.0008	Tukey-Kramer	0.0137
Fuel2	E	F	0.01472	0.1092	107	0.13	0.8930	Tukey-Kramer	1.0000
Fuel2	E	G	0.5816	0.1495	107	3.89	0.0002	Tukey-Kramer	0.0032
Fuel2	F	G	0.5668	0.1495	107	3.79	0.0002	Tukey-Kramer	0.0045

Table 17: Test the Significance of the Fixed Effect – Fuel Type for CO_2w

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	4.20	0.0005
Test	1	221	123.90	<.0001
Fuel2*Test	6	221	0.31	0.9327

Table 18: Least of Squares Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		5.8716	354.8162
Fuel2	B		5.8574	349.8134
Fuel2	C		5.8453	345.6062
Fuel2	D		5.8622	351.4966
Fuel2	E		5.8701	354.2844
Fuel2	F		5.8649	352.4469
Fuel2	G		5.8790	357.4516
Test		FTP	5.8414	344.261
Test		UNI	5.8873	360.4308

Table 19: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.01422	0.006328	221	2.25	0.0256	Tukey-Kramer	0.2751
Fuel2	A		C		0.02625	0.006328	221	4.15	<.0001	Tukey-Kramer	0.0009
Fuel2	A		D		0.009435	0.006328	221	1.49	0.1374	Tukey-Kramer	0.7500
Fuel2	A		E		0.001498	0.007097	221	0.21	0.8330	Tukey-Kramer	1.0000
Fuel2	A		F		0.006683	0.007097	221	0.94	0.3474	Tukey-Kramer	0.9653
Fuel2	A		G		-0.00746	0.009998	221	-0.75	0.4567	Tukey-Kramer	0.9895
Fuel2	B		C		0.01204	0.006363	221	1.89	0.0598	Tukey-Kramer	0.4880
Fuel2	B		D		-0.00478	0.006363	221	-0.75	0.4530	Tukey-Kramer	0.9890
Fuel2	B		E		-0.01272	0.007112	221	-1.79	0.0751	Tukey-Kramer	0.5573
Fuel2	B		F		-0.00754	0.007112	221	-1.06	0.2905	Tukey-Kramer	0.9391
Fuel2	B		G		-0.02167	0.01001	221	-2.17	0.0314	Tukey-Kramer	0.3188
Fuel2	C		D		-0.01682	0.006363	221	-2.64	0.0088	Tukey-Kramer	0.1182
Fuel2	C		E		-0.02476	0.007112	221	-3.48	0.0006	Tukey-Kramer	0.0106
Fuel2	C		F		-0.01957	0.007112	221	-2.75	0.0064	Tukey-Kramer	0.0906
Fuel2	C		G		-0.03371	0.01001	221	-3.37	0.0009	Tukey-Kramer	0.0154
Fuel2	D		E		-0.00794	0.007112	221	-1.12	0.2657	Tukey-Kramer	0.9228
Fuel2	D		F		-0.00275	0.007112	221	-0.39	0.6992	Tukey-Kramer	0.9997
Fuel2	D		G		-0.01689	0.01001	221	-1.69	0.0929	Tukey-Kramer	0.6252
Fuel2	E		F		0.005184	0.007529	221	0.69	0.4918	Tukey-Kramer	0.9931
Fuel2	E		G		-0.00895	0.01031	221	-0.87	0.3861	Tukey-Kramer	0.9768
Fuel2	F		G		-0.01414	0.01031	221	-1.37	0.1717	Tukey-Kramer	0.8165
Test		FTP		UNI	-0.04588	0.004121	221	-11.13	<.0001	Tukey-Kramer	<.0001

Table 20: Test the Significance of the Fixed Effect – Fuel Type for $CO_2$1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	5.71	<.0001
Test	1	221	14016.1	<.0001
Fuel2*Test	6	221	0.70	0.6538

Table 21: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		6.1689	477.6604
Fuel2	B		6.1632	474.9455
Fuel2	C		6.1457	466.7062
Fuel2	D		6.1678	477.1353
Fuel2	E		6.1898	487.7485
Fuel2	F		6.1807	483.3302
Fuel2	G		6.1728	479.5269
Test		FTP	5.8885	360.8636
Test		UNI	6.4511	633.3986

Table 22: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.005693	0.007296	221	0.78	0.4360	Tukey-Kramer	0.9866
Fuel2	A		C		0.02325	0.007296	221	3.19	0.0017	Tukey-Kramer	0.0271
Fuel2	A		D		0.001156	0.007296	221	0.16	0.8742	Tukey-Kramer	1.0000
Fuel2	A		E		-0.02087	0.008182	221	-2.55	0.0114	Tukey-Kramer	0.1469
Fuel2	A		F		-0.01175	0.008182	221	-1.44	0.1525	Tukey-Kramer	0.7819
Fuel2	A		G		-0.00390	0.01153	221	-0.34	0.7355	Tukey-Kramer	0.9999
Fuel2	B		C		0.01755	0.007337	221	2.39	0.0176	Tukey-Kramer	0.2067
Fuel2	B		D		-0.00454	0.007337	221	-0.62	0.5369	Tukey-Kramer	0.9962
Fuel2	B		E		-0.02656	0.008200	221	-3.24	0.0014	Tukey-Kramer	0.0231
Fuel2	B		F		-0.01744	0.008200	221	-2.13	0.0345	Tukey-Kramer	0.3406
Fuel2	B		G		-0.00959	0.01154	221	-0.83	0.4067	Tukey-Kramer	0.9815
Fuel2	C		D		-0.02209	0.007337	221	-3.01	0.0029	Tukey-Kramer	0.0453
Fuel2	C		E		-0.04411	0.008200	221	-5.38	<.0001	Tukey-Kramer	<.0001
Fuel2	C		F		-0.03499	0.008200	221	-4.27	<.0001	Tukey-Kramer	0.0006
Fuel2	C		G		-0.02715	0.01154	221	-2.35	0.0195	Tukey-Kramer	0.2243
Fuel2	D		E		-0.02202	0.008200	221	-2.69	0.0078	Tukey-Kramer	0.1068
Fuel2	D		F		-0.01290	0.008200	221	-1.57	0.1170	Tukey-Kramer	0.6994
Fuel2	D		G		-0.00506	0.01154	221	-0.44	0.6618	Tukey-Kramer	0.9995
Fuel2	E		F		0.009119	0.008681	221	1.05	0.2947	Tukey-Kramer	0.9415
Fuel2	E		G		0.01697	0.01189	221	1.43	0.1549	Tukey-Kramer	0.7865
Fuel2	F		G		0.007848	0.01189	221	0.66	0.5098	Tukey-Kramer	0.9945
Test		FTP		UNI	-0.5626	0.004752	221	-118.39	<.0001	Tukey-Kramer	<.0001

Table 23: Test the Significance of the Fixed Effect – Fuel Type for $CO_2$2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	2.10	0.0538
Test	1	221	157.31	<.0001
Fuel2*Test	6	221	0.54	0.7803

Table 24: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		5.8568	349.6036
Fuel2	B		5.8422	344.5365
Fuel2	C		5.8315	340.8696
Fuel2	D		5.8485	346.7139
Fuel2	E		5.8509	347.547
Fuel2	F		5.8478	346.4713
Fuel2	G		5.8679	353.5058
Test		FTP	5.8848	359.5309
Test		UNI	5.8139	334.9228

Table 25: Differences of Least Squares Means

Differencess of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.01454	0.008676	221	1.68	0.0952	Tukey-Kramer	0.6329
Fuel2	A		C		0.02525	0.008676	221	2.91	0.0040	Tukey-Kramer	0.0598
Fuel2	A		D		0.008299	0.008676	221	0.96	0.3399	Tukey-Kramer	0.9625
Fuel2	A		E		0.005901	0.009729	221	0.61	0.5448	Tukey-Kramer	0.9966
Fuel2	A		F		0.008928	0.009729	221	0.92	0.3598	Tukey-Kramer	0.9695
Fuel2	A		G		-0.01110	0.01371	221	-0.81	0.4189	Tukey-Kramer	0.9838
Fuel2	B		C		0.01071	0.008724	221	1.23	0.2208	Tukey-Kramer	0.8827
Fuel2	B		D		-0.00624	0.008724	221	-0.72	0.4751	Tukey-Kramer	0.9916
Fuel2	B		E		-0.00864	0.009751	221	-0.89	0.3766	Tukey-Kramer	0.9744
Fuel2	B		F		-0.00561	0.009751	221	-0.58	0.5655	Tukey-Kramer	0.9974
Fuel2	B		G		-0.02564	0.01372	221	-1.87	0.0630	Tukey-Kramer	0.5035
Fuel2	C		D		-0.01695	0.008724	221	-1.94	0.0533	Tukey-Kramer	0.4541
Fuel2	C		E		-0.01935	0.009751	221	-1.98	0.0484	Tukey-Kramer	0.4275
Fuel2	C		F		-0.01632	0.009751	221	-1.67	0.0955	Tukey-Kramer	0.6341
Fuel2	C		G		-0.03635	0.01372	221	-2.65	0.0087	Tukey-Kramer	0.1166
Fuel2	D		E		-0.00240	0.009751	221	-0.25	0.8060	Tukey-Kramer	1.0000
Fuel2	D		F		0.000630	0.009751	221	0.06	0.9486	Tukey-Kramer	1.0000
Fuel2	D		G		-0.01940	0.01372	221	-1.41	0.1589	Tukey-Kramer	0.7941
Fuel2	E		F		0.003027	0.01032	221	0.29	0.7696	Tukey-Kramer	0.9999
Fuel2	E		G		-0.01700	0.01413	221	-1.20	0.2303	Tukey-Kramer	0.8925
Fuel2	F		G		-0.02003	0.01413	221	-1.42	0.1579	Tukey-Kramer	0.7922
Test		FTP		UNI	0.07087	0.005650	221	12.54	<.0001	Tukey-Kramer	<.0001

Table 26: Test the Significance of the Fixed Effect – Fuel Type for $CO_2$3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	3.07	0.0066
Test	1	221	12166.7	<.0001
Fuel2*Test	6	221	0.50	0.8110

Table 27: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		5.9425	380.886
Fuel2	B		5.9312	376.6062
Fuel2	C		5.9220	373.1573
Fuel2	D		5.9326	377.1338
Fuel2	E		5.9456	382.0685
Fuel2	F		5.9331	377.3224
Fuel2	G		5.9473	382.7186
Test		FTP	5.7132	302.8386
Test		UNI	6.1595	473.1914

Table 28: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.01127	0.006213	221	1.81	0.0710	Tukey-Kramer	0.5399
Fuel2	A		C		0.02048	0.006213	221	3.30	0.0011	Tukey-Kramer	0.0193
Fuel2	A		D		0.009871	0.006213	221	1.59	0.1135	Tukey-Kramer	0.6896
Fuel2	A		E		-0.00313	0.006967	221	-0.45	0.6533	Tukey-Kramer	0.9994
Fuel2	A		F		0.009340	0.006967	221	1.34	0.1814	Tukey-Kramer	0.8320
Fuel2	A		G		-0.00485	0.009816	221	-0.49	0.6217	Tukey-Kramer	0.9989
Fuel2	B		C		0.009211	0.006247	221	1.47	0.1418	Tukey-Kramer	0.7597
Fuel2	B		D		-0.00140	0.006247	221	-0.22	0.8229	Tukey-Kramer	1.0000
Fuel2	B		E		-0.01441	0.006983	221	-2.06	0.0403	Tukey-Kramer	0.3785
Fuel2	B		F		-0.00193	0.006983	221	-0.28	0.7823	Tukey-Kramer	1.0000
Fuel2	B		G		-0.01612	0.009827	221	-1.64	0.1023	Tukey-Kramer	0.6562
Fuel2	C		D		-0.01061	0.006247	221	-1.70	0.0908	Tukey-Kramer	0.6177
Fuel2	C		E		-0.02362	0.006983	221	-3.38	0.0009	Tukey-Kramer	0.0147
Fuel2	C		F		-0.01114	0.006983	221	-1.60	0.1120	Tukey-Kramer	0.6852
Fuel2	C		G		-0.02533	0.009827	221	-2.58	0.0106	Tukey-Kramer	0.1378
Fuel2	D		E		-0.01300	0.006983	221	-1.86	0.0639	Tukey-Kramer	0.5075
Fuel2	D		F		-0.00053	0.006983	221	-0.08	0.9394	Tukey-Kramer	1.0000
Fuel2	D		G		-0.01472	0.009827	221	-1.50	0.1355	Tukey-Kramer	0.7458
Fuel2	E		F		0.01247	0.007392	221	1.69	0.0929	Tukey-Kramer	0.6252
Fuel2	E		G		-0.00172	0.01012	221	-0.17	0.8655	Tukey-Kramer	1.0000
Fuel2	F		G		-0.01419	0.01012	221	-1.40	0.1623	Tukey-Kramer	0.8004
Test		FTP		UNI	-0.4463	0.004046	221	-110.30	<.0001	Tukey-Kramer	<.0001

Table 29: Test the Significance of the Fixed Effect – Fuel Type for NO_x3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	3.11	0.0060
Test	1	221	70.01	<.0001
Fuel2*Test	6	221	0.71	0.6395

Table 30: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-5.2560	0.005216
Fuel2	B		-5.0982	0.006108
Fuel2	C		-4.7746	0.008441
Fuel2	D		-4.8360	0.007939
Fuel2	E		-4.9164	0.007325
Fuel2	F		-4.8284	0.007999
Fuel2	G		-5.0409	0.006468
Test		FTP	-5.3325	0.004832
Test		UNI	-4.5963	0.010089

Table 31: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		-0.1578	0.1351	221	-1.17	0.2440	Tukey-Kramer	0.9053
Fuel2	A		C		-0.4814	0.1351	221	-3.56	0.0004	Tukey-Kramer	0.0080
Fuel2	A		D		-0.4200	0.1351	221	-3.11	0.0021	Tukey-Kramer	0.0341
Fuel2	A		E		-0.3396	0.1514	221	-2.24	0.0259	Tukey-Kramer	0.2775
Fuel2	A		F		-0.4276	0.1514	221	-2.82	0.0052	Tukey-Kramer	0.0754
Fuel2	A		G		-0.2151	0.2133	221	-1.01	0.3144	Tukey-Kramer	0.9517
Fuel2	B		C		-0.3236	0.1358	221	-2.38	0.0181	Tukey-Kramer	0.2111
Fuel2	B		D		-0.2622	0.1358	221	-1.93	0.0549	Tukey-Kramer	0.4628
Fuel2	B		E		-0.1817	0.1518	221	-1.20	0.2325	Tukey-Kramer	0.8946
Fuel2	B		F		-0.2698	0.1518	221	-1.78	0.0769	Tukey-Kramer	0.5648
Fuel2	B		G		-0.05729	0.2136	221	-0.27	0.7888	Tukey-Kramer	1.0000
Fuel2	C		D		0.06144	0.1358	221	0.45	0.6515	Tukey-Kramer	0.9993
Fuel2	C		E		0.1419	0.1518	221	0.93	0.3510	Tukey-Kramer	0.9665
Fuel2	C		F		0.05383	0.1518	221	0.35	0.7232	Tukey-Kramer	0.9998
Fuel2	C		G		0.2663	0.2136	221	1.25	0.2137	Tukey-Kramer	0.8748
Fuel2	D		E		0.08044	0.1518	221	0.53	0.5967	Tukey-Kramer	0.9984
Fuel2	D		F		-0.00761	0.1518	221	-0.05	0.9601	Tukey-Kramer	1.0000
Fuel2	D		G		0.2049	0.2136	221	0.96	0.3384	Tukey-Kramer	0.9620
Fuel2	E		F		-0.08805	0.1607	221	-0.55	0.5844	Tukey-Kramer	0.9981
Fuel2	E		G		0.1244	0.2200	221	0.57	0.5722	Tukey-Kramer	0.9977
Fuel2	F		G		0.2125	0.2200	221	0.97	0.3352	Tukey-Kramer	0.9607
Test		FTP		UNI	-0.7362	0.08798	221	-8.37	<.0001	Tukey-Kramer	<.0001

Table 32: Test the Significance of the Fixed Effect – Fuel Type for Few

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	7.70	<.0001
Test	1	221	84.47	<.0001
Fuel2*Test	6	221	0.63	0.7022

Table 33: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.04332	23.08403
Fuel2	B		0.04367	22.89902
Fuel2	C		0.04427	22.58866
Fuel2	D		0.04247	23.54603
Fuel2	E		0.04379	22.83626
Fuel2	F		0.04436	22.54283
Fuel2	G		0.04424	22.60398
Test		FTP	0.04279	23.36995
Test		UNI	0.04467	22.38639

Table 34: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	**A**		**B**		-0.00035	0.000314	221	-1.12	0.2655	Tukey-Kramer	0.9226
Fuel2	**A**		**C**		-0.00094	0.000314	221	-3.01	0.0029	Tukey-Kramer	0.0455
Fuel2	**A**		**D**		0.000858	0.000314	221	2.74	0.0067	Tukey-Kramer	0.0945
Fuel2	**A**		**E**		-0.00047	0.000352	221	-1.33	0.1860	Tukey-Kramer	0.8388
Fuel2	**A**		**F**		-0.00104	0.000352	221	-2.95	0.0036	Tukey-Kramer	0.0544
Fuel2	**A**		**G**		-0.00092	0.000496	221	-1.86	0.0647	Tukey-Kramer	0.5114
Fuel2	**B**		**C**		-0.00059	0.000316	221	-1.88	0.0611	Tukey-Kramer	0.4941
Fuel2	**B**		**D**		0.001209	0.000316	221	3.83	0.0002	Tukey-Kramer	0.0031
Fuel2	**B**		**E**		-0.00012	0.000353	221	-0.33	0.7414	Tukey-Kramer	0.9999
Fuel2	**B**		**F**		-0.00069	0.000353	221	-1.95	0.0530	Tukey-Kramer	0.4525
Fuel2	**B**		**G**		-0.00057	0.000496	221	-1.15	0.2519	Tukey-Kramer	0.9121
Fuel2	**C**		**D**		0.001803	0.000316	221	5.71	<.0001	Tukey-Kramer	<.0001
Fuel2	**C**		**E**		0.000477	0.000353	221	1.35	0.1772	Tukey-Kramer	0.8255
Fuel2	**C**		**F**		-0.00009	0.000353	221	-0.26	0.7939	Tukey-Kramer	1.0000
Fuel2	**C**		**G**		0.000024	0.000496	221	0.05	0.9618	Tukey-Kramer	1.0000
Fuel2	**D**		**E**		-0.00133	0.000353	221	-3.76	0.0002	Tukey-Kramer	0.0041
Fuel2	**D**		**F**		-0.00189	0.000353	221	-5.37	<.0001	Tukey-Kramer	<.0001
Fuel2	**D**		**G**		-0.00178	0.000496	221	-3.58	0.0004	Tukey-Kramer	0.0075
Fuel2	**E**		**F**		-0.00057	0.000373	221	-1.53	0.1285	Tukey-Kramer	0.7290
Fuel2	**E**		**G**		-0.00045	0.000511	221	-0.89	0.3759	Tukey-Kramer	0.9742
Fuel2	**F**		**G**		0.000116	0.000511	221	0.23	0.8206	Tukey-Kramer	1.0000
Test		**FTP**		**UNI**	-0.00188	0.000204	221	-9.19	<.0001	Tukey-Kramer	<.0001

Table 35: Test the Significance of the Fixed Effect – Fuel Type for FE2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	221	3.98	0.0008
Test	1	221	110.25	<.0001
Fuel2*Test	6	221	0.70	0.6486

Table 36: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.04255	23.50176
Fuel2	B		0.04285	23.33722
Fuel2	C		0.04341	23.03617
Fuel2	D		0.04172	23.96932
Fuel2	E		0.04279	23.36995
Fuel2	F		0.04346	23.00966
Fuel2	G		0.04357	22.95157
Test		FTP	0.04431	22.56827
Test		UNI	0.04151	24.09058

Table 37: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		-0.00030	0.000409	221	-0.74	0.4573	Tukey-Kramer	0.9896
Fuel2	A		C		-0.00086	0.000409	221	-2.10	0.0367	Tukey-Kramer	0.3553
Fuel2	A		D		0.000825	0.000409	221	2.01	0.0452	Tukey-Kramer	0.4085
Fuel2	A		E		-0.00024	0.000459	221	-0.53	0.5947	Tukey-Kramer	0.9983
Fuel2	A		F		-0.00091	0.000459	221	-1.99	0.0483	Tukey-Kramer	0.4267
Fuel2	A		G		-0.00102	0.000647	221	-1.58	0.1146	Tukey-Kramer	0.6927
Fuel2	B		C		-0.00056	0.000412	221	-1.35	0.1785	Tukey-Kramer	0.8275
Fuel2	B		D		0.001129	0.000412	221	2.74	0.0066	Tukey-Kramer	0.0924
Fuel2	B		E		0.000060	0.000460	221	0.13	0.8960	Tukey-Kramer	1.0000
Fuel2	B		F		-0.00061	0.000460	221	-1.32	0.1886	Tukey-Kramer	0.8426
Fuel2	B		G		-0.00072	0.000647	221	-1.11	0.2675	Tukey-Kramer	0.9241
Fuel2	C		D		0.001685	0.000412	221	4.09	<.0001	Tukey-Kramer	0.0012
Fuel2	C		E		0.000616	0.000460	221	1.34	0.1821	Tukey-Kramer	0.8331
Fuel2	C		F		-0.00005	0.000460	221	-0.11	0.9115	Tukey-Kramer	1.0000
Fuel2	C		G		-0.00016	0.000647	221	-0.25	0.8001	Tukey-Kramer	1.0000
Fuel2	D		E		-0.00107	0.000460	221	-2.32	0.0210	Tukey-Kramer	0.2373
Fuel2	D		F		-0.00174	0.000460	221	-3.77	0.0002	Tukey-Kramer	0.0038
Fuel2	D		G		-0.00185	0.000647	221	-2.86	0.0047	Tukey-Kramer	0.0692
Fuel2	E		F		-0.00067	0.000487	221	-1.37	0.1722	Tukey-Kramer	0.8175
Fuel2	E		G		-0.00078	0.000667	221	-1.17	0.2435	Tukey-Kramer	0.9048
Fuel2	F		G		-0.00011	0.000667	221	-0.17	0.8657	Tukey-Kramer	1.0000
Test		FTP		UNI	0.002800	0.000267	221	10.50	<.0001	Tukey-Kramer	<.0001

Table 38: Test the Significance of the Fixed Effect – Fuel Type for PM Mass

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	157	2.48	0.0258
Test	1	157	3.55	0.0612
Fuel2*Test	6	157	0.53	0.7866

Table 39: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.07514	0.958035
Fuel2	B		0.1753	1.071604
Fuel2	C		-0.2996	0.621115
Fuel2	D		0.2206	1.126825
Fuel2	E		0.2797	1.202733
Fuel2	F		-0.00827	0.871764
Fuel2	G		-0.1642	0.728572
Test		FTP	-0.07196	0.810568
Test		UNI	0.1516	1.043695

Table 40: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		-0.1002	0.1800	157	-0.56	0.5786	Tukey-Kramer	0.9979
Fuel2	A		C		0.3748	0.1767	157	2.12	0.0355	Tukey-Kramer	0.3456
Fuel2	A		D		-0.1454	0.1910	157	-0.76	0.4474	Tukey-Kramer	0.9882
Fuel2	A		E		-0.2046	0.1767	157	-1.16	0.2488	Tukey-Kramer	0.9087
Fuel2	A		F		0.08341	0.1767	157	0.47	0.6375	Tukey-Kramer	0.9992
Fuel2	A		G		0.2393	0.3198	157	0.75	0.4554	Tukey-Kramer	0.9892
Fuel2	B		C		0.4749	0.1767	157	2.69	0.0080	Tukey-Kramer	0.1082
Fuel2	B		D		-0.04528	0.1910	157	-0.24	0.8129	Tukey-Kramer	1.0000
Fuel2	B		E		-0.1044	0.1767	157	-0.59	0.5555	Tukey-Kramer	0.9970
Fuel2	B		F		0.1836	0.1767	157	1.04	0.3004	Tukey-Kramer	0.9441
Fuel2	B		G		0.3395	0.3182	157	1.07	0.2877	Tukey-Kramer	0.9368
Fuel2	C		D		-0.5202	0.1883	157	-2.76	0.0064	Tukey-Kramer	0.0901
Fuel2	C		E		-0.5793	0.1733	157	-3.34	0.0010	Tukey-Kramer	0.0176
Fuel2	C		F		-0.2914	0.1733	157	-1.68	0.0947	Tukey-Kramer	0.6297
Fuel2	C		G		-0.1355	0.3170	157	-0.43	0.6697	Tukey-Kramer	0.9995
Fuel2	D		E		-0.05911	0.1883	157	-0.31	0.7540	Tukey-Kramer	0.9999
Fuel2	D		F		0.2289	0.1883	157	1.22	0.2261	Tukey-Kramer	0.8873
Fuel2	D		G		0.3847	0.3226	157	1.19	0.2347	Tukey-Kramer	0.8960
Fuel2	E		F		0.2880	0.1733	157	1.66	0.0986	Tukey-Kramer	0.6426
Fuel2	E		G		0.4439	0.3170	157	1.40	0.1635	Tukey-Kramer	0.8012
Fuel2	F		G		0.1559	0.3170	157	0.49	0.6236	Tukey-Kramer	0.9989
Test		FTP		UNI	-0.2235	0.1186	157	-1.89	0.0612	Tukey-Kramer	0.0612

Table 41: Test the Significance of the Fixed Effect – Fuel Type for Weighted Particle Number

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	190	10.45	<.0001
Test	1	190	9.07	0.0029
Fuel2*Test	6	190	0.77	0.5935

Table 42: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		28.1397	1.66E+12
Fuel2	B		27.9726	1.41E+12
Fuel2	C		27.8568	1.25E+12
Fuel2	D		28.2121	1.79E+12
Fuel2	E		28.2363	1.83E+12
Fuel2	F		27.5124	8.88E+11
Fuel2	G		27.9655	1.4E+12
Test		FTP	27.8897	1.3E+12
Test		UNI	28.0804	1.57E+12

Table 43: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.1671	0.09986	190	1.67	0.0959	Tukey-Kramer	0.6345
Fuel2	A		C		0.2829	0.1018	190	2.78	0.0060	Tukey-Kramer	0.0856
Fuel2	A		D		-0.07240	0.09934	190	-0.73	0.4670	Tukey-Kramer	0.9907
Fuel2	A		E		-0.09663	0.1094	190	-0.88	0.3781	Tukey-Kramer	0.9747
Fuel2	A		F		0.6273	0.1105	190	5.68	<.0001	Tukey-Kramer	<.0001
Fuel2	A		G		0.1742	0.1578	190	1.10	0.2710	Tukey-Kramer	0.9263
Fuel2	B		C		0.1158	0.09672	190	1.20	0.2327	Tukey-Kramer	0.8945
Fuel2	B		D		-0.2395	0.09569	190	-2.50	0.0132	Tukey-Kramer	0.1641
Fuel2	B		E		-0.2637	0.1050	190	-2.51	0.0128	Tukey-Kramer	0.1608
Fuel2	B		F		0.4602	0.1063	190	4.33	<.0001	Tukey-Kramer	0.0005
Fuel2	B		G		0.007112	0.1541	190	0.05	0.9632	Tukey-Kramer	1.0000
Fuel2	C		D		-0.3553	0.09744	190	-3.65	0.0003	Tukey-Kramer	0.0062
Fuel2	C		E		-0.3796	0.1066	190	-3.56	0.0005	Tukey-Kramer	0.0083
Fuel2	C		F		0.3444	0.1080	190	3.19	0.0017	Tukey-Kramer	0.0274
Fuel2	C		G		-0.1087	0.1548	190	-0.70	0.4835	Tukey-Kramer	0.9924
Fuel2	D		E		-0.02423	0.1063	190	-0.23	0.8200	Tukey-Kramer	1.0000
Fuel2	D		F		0.6997	0.1075	190	6.51	<.0001	Tukey-Kramer	<.0001
Fuel2	D		G		0.2466	0.1554	190	1.59	0.1141	Tukey-Kramer	0.6906
Fuel2	E		F		0.7239	0.1126	190	6.43	<.0001	Tukey-Kramer	<.0001
Fuel2	E		G		0.2709	0.1579	190	1.72	0.0879	Tukey-Kramer	0.6067
Fuel2	F		G		-0.4531	0.1599	190	-2.83	0.0051	Tukey-Kramer	0.0740
Test		FTP		UNI	-0.1906	0.06329	190	-3.01	0.0029	Tukey-Kramer	0.0029

Table 44: Test the Significance of the Fixed Effect – Fuel Type for Particle Number1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	195	4.38	0.0004
Test	1	195	145.23	<.0001
Fuel2*Test	6	195	2.38	0.0306

Table 45: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	29.0172	4E+12
Fuel2*Test	A	UNI	30.0705	1.15E+13
Fuel2*Test	B	FTP	29.1402	4.52E+12
Fuel2*Test	B	UNI	29.7334	8.19E+12
Fuel2*Test	C	FTP	28.9113	3.6E+12
Fuel2*Test	C	UNI	29.6288	7.37E+12
Fuel2*Test	D	FTP	29.2205	4.9E+12
Fuel2*Test	D	UNI	30.0485	1.12E+13
Fuel2*Test	E	FTP	29.1620	4.62E+12
Fuel2*Test	E	UNI	30.1831	1.28E+13
Fuel2*Test	F	FTP	29.1425	4.53E+12
Fuel2*Test	F	UNI	29.5389	6.74E+12
Fuel2*Test	G	FTP	29.0451	4.11E+12
Fuel2*Test	G	UNI	29.7029	7.94E+12

Table 46: Differences of Least Squares Means (Test FTP)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	B	-0.07507	0.1256	94	-0.60	0.5514	Tukey-Kramer	0.9967
Fuel2	A	C	0.1455	0.1234	94	1.18	0.2415	Tukey-Kramer	0.9004
Fuel2	A	D	-0.1697	0.1233	94	-1.38	0.1720	Tukey-Kramer	0.8129
Fuel2	A	E	-0.1397	0.1396	94	-1.00	0.3197	Tukey-Kramer	0.9527
Fuel2	A	F	-0.1237	0.1432	94	-0.86	0.3897	Tukey-Kramer	0.9769
Fuel2	A	G	0.01826	0.1987	94	0.09	0.9270	Tukey-Kramer	1.0000
Fuel2	B	C	0.2206	0.1210	94	1.82	0.0714	Tukey-Kramer	0.5360
Fuel2	B	D	-0.09466	0.1216	94	-0.78	0.4382	Tukey-Kramer	0.9865
Fuel2	B	E	-0.06458	0.1378	94	-0.47	0.6404	Tukey-Kramer	0.9992
Fuel2	B	F	-0.04867	0.1411	94	-0.34	0.7309	Tukey-Kramer	0.9999
Fuel2	B	G	0.09333	0.1979	94	0.47	0.6382	Tukey-Kramer	0.9991
Fuel2	C	D	-0.3152	0.1195	94	-2.64	0.0098	Tukey-Kramer	0.1266
Fuel2	C	E	-0.2851	0.1369	94	-2.08	0.0400	Tukey-Kramer	0.3713
Fuel2	C	F	-0.2692	0.1402	94	-1.92	0.0579	Tukey-Kramer	0.4725
Fuel2	C	G	-0.1272	0.1972	94	-0.65	0.5204	Tukey-Kramer	0.9950
Fuel2	D	E	0.03007	0.1380	94	0.22	0.8280	Tukey-Kramer	1.0000
Fuel2	D	F	0.04598	0.1411	94	0.33	0.7453	Tukey-Kramer	0.9999
Fuel2	D	G	0.1880	0.1984	94	0.95	0.3458	Tukey-Kramer	0.9636
Fuel2	E	F	0.01591	0.1518	94	0.10	0.9168	Tukey-Kramer	1.0000
Fuel2	E	G	0.1579	0.2040	94	0.77	0.4408	Tukey-Kramer	0.9869
Fuel2	F	G	0.1420	0.2089	94	0.68	0.4984	Tukey-Kramer	0.9934

Table 47: Differences of Least Squares Means (Test UNI)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	B	0.3356	0.1432	95	2.34	0.0212	Tukey-Kramer	0.2344
Fuel2	A	C	0.4202	0.1453	95	2.89	0.0047	Tukey-Kramer	0.0685
Fuel2	A	D	0.01980	0.1463	95	0.14	0.8926	Tukey-Kramer	1.0000
Fuel2	A	E	-0.09458	0.1570	95	-0.60	0.5484	Tukey-Kramer	0.9966
Fuel2	A	F	0.5497	0.1570	95	3.50	0.0007	Tukey-Kramer	0.0122
Fuel2	A	G	0.3392	0.2315	95	1.47	0.1461	Tukey-Kramer	0.7644
Fuel2	B	C	0.08456	0.1366	95	0.62	0.5374	Tukey-Kramer	0.9961
Fuel2	B	D	-0.3158	0.1383	95	-2.28	0.0246	Tukey-Kramer	0.2626
Fuel2	B	E	-0.4302	0.1478	95	-2.91	0.0045	Tukey-Kramer	0.0651
Fuel2	B	F	0.2141	0.1478	95	1.45	0.1507	Tukey-Kramer	0.7738
Fuel2	B	G	0.003617	0.2228	95	0.02	0.9871	Tukey-Kramer	1.0000
Fuel2	C	D	-0.4004	0.1404	95	-2.85	0.0053	Tukey-Kramer	0.0759
Fuel2	C	E	-0.5148	0.1510	95	-3.41	0.0010	Tukey-Kramer	0.0161
Fuel2	C	F	0.1295	0.1510	95	0.86	0.3932	Tukey-Kramer	0.9778
Fuel2	C	G	-0.08094	0.2239	95	-0.36	0.7185	Tukey-Kramer	0.9998
Fuel2	D	E	-0.1144	0.1519	95	-0.75	0.4532	Tukey-Kramer	0.9886
Fuel2	D	F	0.5299	0.1519	95	3.49	0.0007	Tukey-Kramer	0.0126
Fuel2	D	G	0.3194	0.2261	95	1.41	0.1609	Tukey-Kramer	0.7936
Fuel2	E	F	0.6443	0.1552	95	4.15	<.0001	Tukey-Kramer	0.0014
Fuel2	E	G	0.4338	0.2276	95	1.91	0.0597	Tukey-Kramer	0.4816
Fuel2	F	G	-0.2105	0.2276	95	-0.92	0.3575	Tukey-Kramer	0.9677

Table 48: Test the Significance of the Fixed Effect – Fuel Type for Particle Number2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	192	3.53	0.0025
Test	1	192	51.89	<.0001
Fuel2*Test	6	192	0.88	0.5118

Table 49: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		27.4607	8.43E+11
Fuel2	B		27.2561	6.87E+11
Fuel2	C		27.0576	5.64E+11
Fuel2	D		27.4043	7.97E+11
Fuel2	E		27.4790	8.59E+11
Fuel2	F		26.7372	4.09E+11
Fuel2	G		27.3042	7.21E+11
Test		FTP	26.8284	4.48E+11
Test		UNI	27.6571	1.03E+12

Table 50: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		B		0.2046	0.1819	192	1.12	0.2620	Tukey-Kramer	0.9198
Fuel2	A		C		0.4031	0.1821	192	2.21	0.0280	Tukey-Kramer	0.2931
Fuel2	A		D		0.05640	0.1810	192	0.31	0.7557	Tukey-Kramer	0.9999
Fuel2	A		E		-0.01830	0.1989	192	-0.09	0.9268	Tukey-Kramer	1.0000
Fuel2	A		F		0.7235	0.2010	192	3.60	0.0004	Tukey-Kramer	0.0073
Fuel2	A		G		0.1565	0.2873	192	0.54	0.5866	Tukey-Kramer	0.9981
Fuel2	B		C		0.1985	0.1739	192	1.14	0.2550	Tukey-Kramer	0.9143
Fuel2	B		D		-0.1482	0.1743	192	-0.85	0.3964	Tukey-Kramer	0.9792
Fuel2	B		E		-0.2229	0.1913	192	-1.17	0.2454	Tukey-Kramer	0.9062
Fuel2	B		F		0.5189	0.1936	192	2.68	0.0080	Tukey-Kramer	0.1090
Fuel2	B		G		-0.04810	0.2807	192	-0.17	0.8641	Tukey-Kramer	1.0000
Fuel2	C		D		-0.3467	0.1743	192	-1.99	0.0481	Tukey-Kramer	0.4248
Fuel2	C		E		-0.4214	0.1927	192	-2.19	0.0299	Tukey-Kramer	0.3073
Fuel2	C		F		0.3205	0.1953	192	1.64	0.1024	Tukey-Kramer	0.6558
Fuel2	C		G		-0.2466	0.2811	192	-0.88	0.3814	Tukey-Kramer	0.9756
Fuel2	D		E		-0.07470	0.1935	192	-0.39	0.6999	Tukey-Kramer	0.9997
Fuel2	D		F		0.6671	0.1956	192	3.41	0.0008	Tukey-Kramer	0.0137
Fuel2	D		G		0.1001	0.2829	192	0.35	0.7239	Tukey-Kramer	0.9998
Fuel2	E		F		0.7418	0.2052	192	3.61	0.0004	Tukey-Kramer	0.0069
Fuel2	E		G		0.1748	0.2877	192	0.61	0.5443	Tukey-Kramer	0.9965
Fuel2	F		G		-0.5670	0.2913	192	-1.95	0.0530	Tukey-Kramer	0.4522
Test		FTP		UNI	-0.8288	0.1151	192	-7.20	<.0001	Tukey-Kramer	<.0001

Table 51: Test the Significance of the Fixed Effect – Fuel Type for Particle Number3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	192	13.09	<.0001
Test	1	192	0.18	0.6747
Fuel2*Test	6	192	2.16	0.0686

Table 52: Least Squares Means

Least Squares Means			
Effect	**Fuel2**	**Estimate**	**Back transformed**
Fuel2	A	27.1502	6.18E+11
Fuel2	B	26.7608	4.19E+11
Fuel2	C	26.7268	4.05E+11
Fuel2	D	27.0328	5.5E+11
Fuel2	E	26.8675	4.66E+11
Fuel2	F	26.0422	2.04E+11
Fuel2	G	27.1397	6.12E+11

Table 53: Mixed Model Analysis for *O*-xylene Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	B	-0.1155	0.1118	97	-1.03	0.3040	0.9450
A	C	-0.1717	0.1102	97	-1.56	0.1226	0.7094
A	D	-0.2779	0.1118	97	-2.48	0.0147	0.1764
A	E	-0.2167	0.1204	97	-1.80	0.0749	0.5511
A	F	0.2651	0.1204	97	2.20	0.0300	0.3042
A	G	-0.1382	0.1809	97	-0.76	0.4468	0.9878
B	C	-0.05614	0.1134	97	-0.50	0.6217	0.9989
B	D	-0.1624	0.1148	97	-1.41	0.1605	0.7929
B	E	-0.1012	0.1238	97	-0.82	0.4157	0.9826
B	F	0.3806	0.1238	97	3.07	0.0027	0.0421
B	G	-0.02268	0.1836	97	-0.12	0.9020	1.0000
C	D	-0.1063	0.1134	97	-0.94	0.3512	0.9656
C	E	-0.04505	0.1211	97	-0.37	0.7107	0.9998
C	F	0.4368	0.1211	97	3.61	0.0005	0.0086
C	G	0.03346	0.1814	97	0.18	0.8541	1.0000
D	E	0.06120	0.1228	97	0.50	0.6194	0.9988
D	F	0.5430	0.1228	97	4.42	<.0001	0.0005
D	G	0.1397	0.1821	97	0.77	0.4449	0.9875
E	F	0.4818	0.1255	97	3.84	0.0002	0.0040
E	G	0.07851	0.1837	97	0.43	0.6701	0.9995
F	G	-0.4033	0.1837	97	-2.19	0.0306	0.3079

Table 54: Least Square Mean (LSM) Values for Formaldehyde

Fuel	Formaldehyde W	
ANOVA p-value	0.4216	
	LSM (estimate)	LSM (back transformed)
A	5.9480	382.9866
B	5.5961	269.3738
C	5.8086	333.1524
D	5.8108	333.8861
E	5.6992	298.6284
F	5.6292	278.4393
G	6.1695	477.9471

Table 55: Least Square Mean (LSM) Values for Acetaldehyde

Fuel	Acetaldehyde W	
ANOVA p-value	0.0285	
	LSM (estimate)	LSM (back transformed)
A	5.7426	311.8742
B	5.7293	307.7538
C	5.7575	316.5559
D	5.3232	205.039
E	5.4624	235.6623
F	5.1549	173.2785
G	6.1695	477.9471

Table 56: Mixed Model Analysis for Acetaldehyde Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	B	0.01329	0.2004	103	0.07	0.9473	1.0000
A	C	-0.01496	0.1976	103	-0.08	0.9398	1.0000
A	D	0.4194	0.1951	103	2.15	0.0339	0.3320
A	E	0.2802	0.2237	103	1.25	0.2132	0.8715
A	F	0.5877	0.2237	103	2.63	0.0099	0.1287
A	G	-0.1312	0.3095	103	-0.42	0.6724	0.9995
B	C	-0.02825	0.2048	103	-0.14	0.8906	1.0000
B	D	0.4061	0.2025	103	2.01	0.0476	0.4179
B	E	0.2669	0.2304	103	1.16	0.2494	0.9078
B	F	0.5744	0.2304	103	2.49	0.0143	0.1727
B	G	-0.1445	0.3147	103	-0.46	0.6470	0.9993
C	D	0.4343	0.1997	103	2.17	0.0320	0.3185
C	E	0.2952	0.2274	103	1.30	0.1973	0.8515
C	F	0.6026	0.2274	103	2.65	0.0093	0.1222
C	G	-0.1163	0.3133	103	-0.37	0.7113	0.9998
D	E	-0.1392	0.2247	103	-0.62	0.5370	0.9961
D	F	0.1683	0.2247	103	0.75	0.4555	0.9890
D	G	-0.5506	0.3102	103	-1.78	0.0788	0.5677
E	F	0.3075	0.2420	103	1.27	0.2067	0.8636
E	G	-0.4114	0.3217	103	-1.28	0.2038	0.8600
F	G	-0.7189	0.3217	103	-2.23	0.0276	0.2864

Table 57: Test the Significance of the Fixed Effect – Fuel Type for Butyraldehyde

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	6	65	3.74	0.0030

Table 58: Least Square Means

Least Squares Means			
Effect	**Fuel2**	**Estimate**	**Back transformed**
Fuel2	A	3.9184	49.31987
Fuel2	B	4.0239	54.91876
Fuel2	C	2.8261	15.8795
Fuel2	D	4.8175	122.6556
Fuel2	E	3.5651	34.34299
Fuel2	F	4.9876	145.5842
Fuel2	G	5.2947	198.2778

Table 59: Differences of Least Squares Means

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	B	-0.1054	0.5936	65	-0.18	0.8596	Tukey-Kramer	1.0000
Fuel2	A	C	1.0923	0.5785	65	1.89	0.0635	Tukey-Kramer	0.4953
Fuel2	A	D	-0.8991	0.5654	65	-1.59	0.1166	Tukey-Kramer	0.6889
Fuel2	A	E	0.3534	0.5512	65	0.64	0.5237	Tukey-Kramer	0.9951
Fuel2	A	F	-1.0691	0.5512	65	-1.94	0.0568	Tukey-Kramer	0.4624
Fuel2	A	G	-1.3763	0.9236	65	-1.49	0.1410	Tukey-Kramer	0.7496
Fuel2	B	C	1.1978	0.6055	65	1.98	0.0522	Tukey-Kramer	0.4382
Fuel2	B	D	-0.7936	0.5936	65	-1.34	0.1859	Tukey-Kramer	0.8319
Fuel2	B	E	0.4588	0.5805	65	0.79	0.4322	Tukey-Kramer	0.9851
Fuel2	B	F	-0.9637	0.5805	65	-1.66	0.1017	Tukey-Kramer	0.6445
Fuel2	B	G	-1.2708	0.9450	65	-1.34	0.1833	Tukey-Kramer	0.8281
Fuel2	C	D	-1.9914	0.5785	65	-3.44	0.0010	Tukey-Kramer	0.0167
Fuel2	C	E	-0.7390	0.5648	65	-1.31	0.1954	Tukey-Kramer	0.8457
Fuel2	C	F	-2.1615	0.5648	65	-3.83	0.0003	Tukey-Kramer	0.0052
Fuel2	C	G	-2.4686	0.9369	65	-2.63	0.0105	Tukey-Kramer	0.1326
Fuel2	D	E	1.2524	0.5512	65	2.27	0.0264	Tukey-Kramer	0.2732
Fuel2	D	F	-0.1701	0.5512	65	-0.31	0.7586	Tukey-Kramer	0.9999
Fuel2	D	G	-0.4772	0.9236	65	-0.52	0.6071	Tukey-Kramer	0.9985
Fuel2	E	F	-1.4225	0.5241	65	-2.71	0.0085	Tukey-Kramer	0.1111
Fuel2	E	G	-1.7296	0.9134	65	-1.89	0.0627	Tukey-Kramer	0.4919
Fuel2	F	G	-0.3071	0.9134	65	-0.34	0.7378	Tukey-Kramer	0.9999

FFV Vehicles:

Table 60: Test the Significance of the Fixed Effect – Fuel Type for THC3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	4.31	0.0102
Test	1	39	56.83	<.0001
Fuel2*Test	3	39	1.54	0.2192

Table 61: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-3.9881	0.016035
Fuel2	H		-3.9124	0.017492
Fuel2	I		-3.7437	0.021166
Fuel2	J		-4.1551	0.013184
Test		FTP	-4.2600	0.011622
Test		UNI	-3.6397	0.02376

Table 62: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.07576	0.1186	42	-0.64	0.5264	Tukey-Kramer	0.9188
Fuel2	A		I		-0.2444	0.1186	42	-2.06	0.0455	Tukey-Kramer	0.1827
Fuel2	A		J		0.1670	0.1186	42	1.41	0.1664	Tukey-Kramer	0.5012
Fuel2	H		I		-0.1687	0.1186	42	-1.42	0.1624	Tukey-Kramer	0.4929
Fuel2	H		J		0.2428	0.1186	42	2.05	0.0469	Tukey-Kramer	0.1874
Fuel2	I		J		0.4114	0.1186	42	3.47	0.0012	Tukey-Kramer	0.0064
Test		FTP		UNI	-0.6203	0.08386	42	-7.40	<.0001	Tukey-Kramer	<.0001

Table 63: Test the Significance of the Fixed Effect – Fuel Type for NMHCw

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	3.45	0.0256
Test	1	39	33.06	<.0001
Fuel2*Test	3	39	0.41	0.7470

Table 64: Least Squares Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-3.6053	0.027179
Fuel2	H		-3.7674	0.023112
Fuel2	I		-3.9516	0.019224
Fuel2	J		-3.7832	0.02275
Test		FTP	-3.5579	0.028499
Test		UNI	-3.9958	0.018393

Table 65: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.1621	0.1055	42	1.54	0.1319	Tukey	0.4255
Fuel2	A		I		0.3463	0.1055	42	3.28	0.0021	Tukey	0.0107
Fuel2	A		J		0.1779	0.1055	42	1.69	0.0992	Tukey	0.3435
Fuel2	H		I		0.1842	0.1055	42	1.75	0.0880	Tukey	0.3131
Fuel2	H		J		0.01581	0.1055	42	0.15	0.8816	Tukey	0.9988
Fuel2	I		J		-0.1684	0.1055	42	-1.60	0.1178	Tukey	0.3914
Test		FTP		UNI	0.4379	0.07458	42	5.87	<.0001	Tukey	<.0001

Table 66: Test the Significance of the Fixed Effect – Fuel Type for CH_4w

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	54.00	<.0001
Test	1	39	15.10	0.0004
Fuel2*Test	3	39	2.90	0.0571

Table 67: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-4.9498	0.007085
Fuel2	H		-4.3979	0.012303
Fuel2	I		-3.9842	0.018607
Fuel2	J		-4.5891	0.010162
Test		FTP	-4.3739	0.012602
Test		UNI	-4.5866	0.010187

Table 68: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.5519	0.07740	39	-7.13	<.0001	Tukey-Kramer	<.0001
Fuel2	A		I		-0.9656	0.07740	39	-12.48	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		-0.3607	0.07740	39	-4.66	<.0001	Tukey-Kramer	0.0002
Fuel2	H		I		-0.4137	0.07740	39	-5.34	<.0001	Tukey-Kramer	<.0001
Fuel2	H		J		0.1912	0.07740	39	2.47	0.0180	Tukey-Kramer	0.0806
Fuel2	I		J		0.6049	0.07740	39	7.82	<.0001	Tukey-Kramer	<.0001
Test		FTP		UNI	0.2127	0.05473	39	3.89	0.0004	Tukey-Kramer	0.0004

Table 69: Test the Significance of the Fixed Effect – Fuel Type for $CH_4$1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	42.83	<.0001
Test	1	39	211.61	<.0001
Fuel2*Test	3	39	0.66	0.5838

Table 70: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-3.1352	0.043491
Fuel2	H		-2.6278	0.072237
Fuel2	I		-2.1330	0.118481
Fuel2	J		-2.8005	0.06078
Test		FTP	-3.1384	0.043352
Test		UNI	-2.2098	0.109723

Table 71: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.5074	0.08916	42	-5.69	<.0001	Tukey-Kramer	<.0001
Fuel2	A		I		-1.0022	0.08916	42	-11.24	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		-0.3347	0.08916	42	-3.75	0.0005	Tukey-Kramer	0.0029
Fuel2	H		I		-0.4948	0.08916	42	-5.55	<.0001	Tukey-Kramer	<.0001
Fuel2	H		J		0.1727	0.08916	42	1.94	0.0595	Tukey-Kramer	0.2284
Fuel2	I		J		0.6675	0.08916	42	7.49	<.0001	Tukey-Kramer	<.0001
Test		FTP		UNI	-0.9285	0.06304	42	-14.73	<.0001	Tukey-Kramer	<.0001

Table 72: Test the Significance of the Fixed Effect – Fuel Type for $CH_4$2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	10.16	<.0001
Test	1	39	15.80	0.0003
Fuel2*Test	3	39	5.16	0.0042

Table 73: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	-5.9964	0.001488
Fuel2*Test	A	UNI	-6.1584	0.001116
Fuel2*Test	H	FTP	-5.8812	0.001791
Fuel2*Test	H	UNI	-5.2772	0.004107
Fuel2*Test	I	FTP	-5.5046	0.003068
Fuel2*Test	I	UNI	-5.2660	0.004164
Fuel2*Test	J	FTP	-6.0631	0.001327
Fuel2*Test	J	UNI	-5.2895	0.004044

Table 74: Differences of Least Squares Means (Test FTP)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.1152	0.1501	19	-0.77	0.4521	Tukey-Kramer	0.8679
Fuel2	A	I	-0.4919	0.1501	19	-3.28	0.0040	Tukey-Kramer	0.0190
Fuel2	A	J	0.06671	0.1501	19	0.44	0.6617	Tukey-Kramer	0.9699
Fuel2	H	I	-0.3766	0.1501	19	-2.51	0.0213	Tukey-Kramer	0.0904
Fuel2	H	J	0.1819	0.1501	19	1.21	0.2403	Tukey-Kramer	0.6269
Fuel2	I	J	0.5586	0.1501	19	3.72	0.0014	Tukey-Kramer	0.0072

Table 75: Test the Significance of the Fixed Effect – Fuel Type for $CH_4$3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	34.28	<.0001
Test	1	39	235.95	<.0001
Fuel2*Test	3	39	0.49	0.6879

Table 76: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-4.4343	0.010863
Fuel2	H		-4.1069	0.015459
Fuel2	I		-3.7325	0.022933
Fuel2	J		-4.4057	0.011208
Test		FTP	-4.5989	0.009063
Test		UNI	-3.7409	0.022733

Table 77: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.3273	0.07756	42	-4.22	0.0001	Tukey-Kramer	0.0007
Fuel2	A		I		-0.7018	0.07756	42	-9.05	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		-0.02852	0.07756	42	-0.37	0.7149	Tukey-Kramer	0.9828
Fuel2	H		I		-0.3745	0.07756	42	-4.83	<.0001	Tukey-Kramer	0.0001
Fuel2	H		J		0.2988	0.07756	42	3.85	0.0004	Tukey-Kramer	0.0021
Fuel2	I		J		0.6733	0.07756	42	8.68	<.0001	Tukey-Kramer	<.0001
Test		FTP		UNI	-0.8580	0.05484	42	-15.65	<.0001	Tukey-Kramer	<.0001

Table 78: Test the Significance of the Fixed Effect – Fuel Type for Cow

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	16.21	<.0001
Test	1	39	15.97	0.0003
Fuel2*Test	3	39	2.04	0.1234

Table 79: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-0.6909	0.501125
Fuel2	H		-0.7842	0.456485
Fuel2	I		-1.2560	0.284791
Fuel2	J		-0.7650	0.465334
Test		FTP	-0.7461	0.474212
Test		UNI	-1.0020	0.367144

Table 80: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.09328	0.09387	42	0.99	0.3261	Tukey-Kramer	0.7538
Fuel2	A		I		0.5651	0.09387	42	6.02	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		0.07404	0.09387	42	0.79	0.4347	Tukey-Kramer	0.8591
Fuel2	H		I		0.4718	0.09387	42	5.03	<.0001	Tukey-Kramer	<.0001
Fuel2	H		J		-0.01923	0.09387	42	-0.20	0.8387	Tukey-Kramer	0.9969
Fuel2	I		J		-0.4910	0.09387	42	-5.23	<.0001	Tukey-Kramer	<.0001
Test		FTP		UNI	0.2559	0.06638	42	3.86	0.0004	Tukey-Kramer	0.0004

Table 81: Test the Significance of the Fixed Effect – Fuel Type for CO1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	6.95	0.0007
Test	1	39	50.65	<.0001
Fuel2*Test	3	39	0.66	0.5809

Table 82: Least Squares Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.9969	2.709868
Fuel2	H		0.9214	2.512806
Fuel2	I		0.4828	1.620606
Fuel2	J		0.9476	2.579511
Test		FTP	0.5154	1.674308
Test		UNI	1.1589	3.186426

Table 83: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.07545	0.1263	42	0.60	0.5535	Tukey-Kramer	0.9323
Fuel2	A		I		0.5140	0.1263	42	4.07	0.0002	Tukey-Kramer	0.0011
Fuel2	A		J		0.04930	0.1263	42	0.39	0.6983	Tukey-Kramer	0.9795
Fuel2	H		I		0.4386	0.1263	42	3.47	0.0012	Tukey-Kramer	0.0064
Fuel2	H		J		-0.02615	0.1263	42	-0.21	0.8370	Tukey-Kramer	0.9968
Fuel2	I		J		-0.4648	0.1263	42	-3.68	0.0007	Tukey-Kramer	0.0036
Test		FTP		UNI	-0.6435	0.08932	42	-7.20	<.0001	Tukey-Kramer	<.0001

Table 84: Test the Significance of the Fixed Effect – Fuel Type for CO2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	3.22	0.0330
Test	1	39	35.62	<.0001
Fuel2*Test	3	39	6.26	0.0014

Table 85: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	-2.6147	0.06319
Fuel2*Test	A	UNI	-1.3884	0.239474
Fuel2*Test	H	FTP	-2.3885	0.081767
Fuel2*Test	H	UNI	-1.3136	0.25885
Fuel2*Test	I	FTP	-2.2276	0.097787
Fuel2*Test	I	UNI	-2.1378	0.107914
Fuel2*Test	J	FTP	-1.8599	0.145688
Fuel2*Test	J	UNI	-1.5655	0.198983

Table 86: Differences of Least Squares Means (Test FTP)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.2262	0.2739	19	-0.83	0.4191	Tukey-Kramer	0.8415
Fuel2	A	I	-0.3871	0.2739	19	-1.41	0.1738	Tukey-Kramer	0.5069
Fuel2	A	J	-0.7548	0.2739	19	-2.76	0.0126	Tukey-Kramer	0.0560
Fuel2	H	I	-0.1609	0.2739	19	-0.59	0.5640	Tukey-Kramer	0.9347
Fuel2	H	J	-0.5286	0.2739	19	-1.93	0.0687	Tukey-Kramer	0.2494
Fuel2	I	J	-0.3677	0.2739	19	-1.34	0.1953	Tukey-Kramer	0.5487

Table 87: Differences of Least Squares Means (Test UNI)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.07486	0.1535	19	-0.49	0.6313	Tukey-Kramer	0.9609
Fuel2	A	I	0.7494	0.1535	19	4.88	0.0001	Tukey-Kramer	0.0006
Fuel2	A	J	0.1770	0.1535	19	1.15	0.2630	Tukey-Kramer	0.6622
Fuel2	H	I	0.8242	0.1535	19	5.37	<.0001	Tukey-Kramer	0.0002
Fuel2	H	J	0.2519	0.1535	19	1.64	0.1172	Tukey-Kramer	0.3806
Fuel2	I	J	-0.5724	0.1535	19	-3.73	0.0014	Tukey-Kramer	0.0071

Table 88: Test the Significance of the Fixed Effect – Fuel Type for CO3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	3.49	0.0246
Test	1	39	7.87	0.0078
Fuel2*Test	3	39	0.41	0.7494

Table 89: Least Squares Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		-1.0470	0.340989
Fuel2	H		-1.3822	0.241026
Fuel2	I		-1.8462	0.147836
Fuel2	J		-1.3686	0.244463
Test		FTP	-1.6580	0.18052
Test		UNI	-1.1640	0.302235

Table 90: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.3352	0.2491	39	1.35	0.1862	Tukey-Kramer	0.5402
Fuel2	A		I		0.7991	0.2491	39	3.21	0.0027	Tukey-Kramer	0.0136
Fuel2	A		J		0.3216	0.2491	39	1.29	0.2043	Tukey-Kramer	0.5741
Fuel2	H		I		0.4639	0.2491	39	1.86	0.0701	Tukey-Kramer	0.2607
Fuel2	H		J		-0.01364	0.2491	39	-0.05	0.9566	Tukey-Kramer	0.9999
Fuel2	I		J		-0.4776	0.2491	39	-1.92	0.0626	Tukey-Kramer	0.2376
Test		FTP		UNI	-0.4940	0.1761	39	-2.80	0.0078	Tukey-Kramer	0.0078

Table 91: Test the Significance of the Fixed Effect – Fuel Type for CO_2w

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	4.48	0.0086
Test	1	39	174.18	<.0001
Fuel2*Test	3	39	3.19	0.0343

Table 92: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	6.1872	486.482
Fuel2*Test	A	UNI	6.2765	531.9237
Fuel2*Test	H	FTP	6.1633	474.993
Fuel2*Test	H	UNI	6.2881	538.1299
Fuel2*Test	I	FTP	6.1674	476.9444
Fuel2*Test	I	UNI	6.2311	508.3143
Fuel2*Test	J	FTP	6.1816	483.7654
Fuel2*Test	J	UNI	6.2742	530.7017

Table 93: Differences of Least Squares Means (Test FTP)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	0.02384	0.01168	19	2.04	0.0553	Tukey-Kramer	0.2082
Fuel2	A	I	0.01979	0.01168	19	1.69	0.1065	Tukey-Kramer	0.3536
Fuel2	A	J	0.005520	0.01168	19	0.47	0.6419	Tukey-Kramer	0.9642
Fuel2	H	I	-0.00405	0.01168	19	-0.35	0.7325	Tukey-Kramer	0.9852
Fuel2	H	J	-0.01832	0.01168	19	-1.57	0.1332	Tukey-Kramer	0.4188
Fuel2	I	J	-0.01427	0.01168	19	-1.22	0.2367	Tukey-Kramer	0.6210

Table 94: Differences of Least Squares Means (Test UNI)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.01162	0.01609	19	-0.72	0.4789	Tukey-Kramer	0.8870
Fuel2	A	I	0.04542	0.01609	19	2.82	0.0109	Tukey-Kramer	0.0490
Fuel2	A	J	0.002344	0.01609	19	0.15	0.8857	Tukey-Kramer	0.9989
Fuel2	H	I	0.05704	0.01609	19	3.54	0.0022	Tukey-Kramer	0.0107
Fuel2	H	J	0.01397	0.01609	19	0.87	0.3963	Tukey-Kramer	0.8212
Fuel2	I	J	-0.04307	0.01609	19	-2.68	0.0149	Tukey-Kramer	0.0655

Table 95: Test the Significance of the Fixed Effect – Fuel Type for $CO_2$1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	3.64	0.0208
Test	1	39	3957.09	<.0001
Fuel2*Test	3	39	2.63	0.0634

Table 96: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		6.5031	667.2068
Fuel2	H		6.4927	660.3038
Fuel2	I		6.4703	645.6774
Fuel2	J		6.5036	667.5405
Test		FTP	6.2354	510.5048
Test		UNI	6.7495	853.6318

Table 97: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.01037	0.01221	42	0.85	0.4008	Tukey-Kramer	0.8308
Fuel2	A		I		0.03278	0.01221	42	2.68	0.0104	Tukey-Kramer	0.0489
Fuel2	A		J		-0.00057	0.01221	42	-0.05	0.9633	Tukey-Kramer	1.0000
Fuel2	H		I		0.02242	0.01221	42	1.84	0.0735	Tukey-Kramer	0.2714
Fuel2	H		J		-0.01093	0.01221	42	-0.90	0.3758	Tukey-Kramer	0.8074
Fuel2	I		J		-0.03335	0.01221	42	-2.73	0.0092	Tukey-Kramer	0.0438
Test		FTP		UNI	-0.5141	0.008636	42	-59.53	<.0001	Tukey-Kramer	<.0001

Table 98: Test the Significance of the Fixed Effect – Fuel Type of $CO_2$2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	4.56	0.0078
Test	1	39	0.72	0.3998
Fuel2*Test	3	39	3.54	0.0232

Table 99: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	6.2177	501.5483
Fuel2*Test	A	UNI	6.2187	502.0501
Fuel2*Test	H	FTP	6.1954	490.4876
Fuel2*Test	H	UNI	6.2365	511.0666
Fuel2*Test	I	FTP	6.1972	491.3713
Fuel2*Test	I	UNI	6.1765	481.3044
Fuel2*Test	J	FTP	6.2118	501.5483
Fuel2*Test	J	UNI	6.2137	502.0501

Table 100: Differencess of Least Squares Means (Test FTP)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	0.02232	0.01356	19	1.65	0.1163	Tukey-Kramer	0.3783
Fuel2	A	I	0.02059	0.01356	19	1.52	0.1455	Tukey-Kramer	0.4468
Fuel2	A	J	0.005924	0.01356	19	0.44	0.6672	Tukey-Kramer	0.9713
Fuel2	H	I	-0.00173	0.01356	19	-0.13	0.8998	Tukey-Kramer	0.9992
Fuel2	H	J	-0.01639	0.01356	19	-1.21	0.2415	Tukey-Kramer	0.6289
Fuel2	I	J	-0.01466	0.01356	19	-1.08	0.2931	Tukey-Kramer	0.7048

Table 101: Differences of Least Squares Means (Test UNI)

Differencess of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.01779	0.01258	19	-1.41	0.1734	Tukey-Kramer	0.5061
Fuel2	A	I	0.04217	0.01258	19	3.35	0.0033	Tukey-Kramer	0.0162
Fuel2	A	J	0.005004	0.01258	19	0.40	0.6952	Tukey-Kramer	0.9781
Fuel2	H	I	0.05997	0.01258	19	4.77	0.0001	Tukey-Kramer	0.0007
Fuel2	H	J	0.02280	0.01258	19	1.81	0.0858	Tukey-Kramer	0.2984
Fuel2	I	J	-0.03717	0.01258	19	-2.95	0.0081	Tukey-Kramer	0.0374

Table 102: Test the Significance of the Fixed Effect – Fuel Type for Few

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	193.59	<.0001
Test	1	39	121.34	<.0001
Fuel2*Test	3	39	1.88	0.1485

Table 103: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.06061	16.49893
Fuel2	H		0.06976	14.33486
Fuel2	I		0.07961	12.56124
Fuel2	J		0.06501	15.38225
Test		FTP	0.06552	15.26252
Test		UNI	0.07197	13.89468

Table 104: Differences of Least Squares Means

Differencess of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.00915	0.000828	39	-11.05	<.0001	Tukey-Kramer	<.0001
Fuel2	A		I		-0.01899	0.000828	39	-22.94	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		-0.00439	0.000828	39	-5.31	<.0001	Tukey-Kramer	<.0001
Fuel2	H		I		-0.00985	0.000828	39	-11.89	<.0001	Tukey-Kramer	<.0001
Fuel2	H		J		0.004755	0.000828	39	5.74	<.0001	Tukey-Kramer	<.0001
Fuel2	I		J		0.01460	0.000828	39	17.63	<.0001	Tukey-Kramer	<.0001
Test		FTP		UNI	-0.00645	0.000586	39	-11.02	<.0001	Tukey-Kramer	<.0001

Table 105: Test the Significance of the Fixed Effect – Fuel Type for FE1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	51.72	<.0001
Test	1	39	368.23	<.0001
Fuel2*Test	3	39	9.64	<.0001

Table 106: Least Squares Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	0.05858	17.07067
Fuel2*Test	A	UNI	0.08069	12.39311
Fuel2*Test	H	FTP	0.06964	14.35956
Fuel2*Test	H	UNI	0.1202	8.319468
Fuel2*Test	I	FTP	0.08244	12.13003
Fuel2*Test	I	UNI	0.1334	7.496252
Fuel2*Test	J	FTP	0.06606	15.13775
Fuel2*Test	J	UNI	0.1124	8.896797

Table 107: Differences of Least Squares Means (Test FTP)

Differences of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.01106	0.001227	19	-9.01	<.0001	Tukey-Kramer	<.0001
Fuel2	A	I	-0.02386	0.001227	19	-19.44	<.0001	Tukey-Kramer	<.0001
Fuel2	A	J	-0.00748	0.001227	19	-6.09	<.0001	Tukey-Kramer	<.0001
Fuel2	H	I	-0.01280	0.001227	19	-10.43	<.0001	Tukey-Kramer	<.0001
Fuel2	H	J	0.003584	0.001227	19	2.92	0.0088	Tukey-Kramer	0.0401
Fuel2	I	J	0.01638	0.001227	19	13.35	<.0001	Tukey-Kramer	<.0001

Table 108: Differences of Least Squares Means (Test UNI)

Differences of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	-0.03947	0.006094	19	-6.48	<.0001	Tukey	<.0001
Fuel2	A	I	-0.05273	0.006094	19	-8.65	<.0001	Tukey	<.0001
Fuel2	A	J	-0.03167	0.006094	19	-5.20	<.0001	Tukey	0.0003
Fuel2	H	I	-0.01326	0.006094	19	-2.18	0.0424	Tukey	0.1659
Fuel2	H	J	0.007803	0.006094	19	1.28	0.2158	Tukey	0.5858
Fuel2	I	J	0.02106	0.006094	19	3.46	0.0026	Tukey	0.0129

Table 109: Test the Significance of the Fixed Effect - Fuel Type for FE2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	175.40	<.0001
Test	1	39	4.23	0.0466
Fuel2*Test	3	39	2.95	0.0645

Table 110: Least Square Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.05966	16.76165
Fuel2	H		0.06890	14.51379
Fuel2	I		0.07852	12.73561
Fuel2	J		0.06386	15.65925
Test		FTP	0.06711	14.90091
Test		UNI	0.06837	14.6263

Table 111: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.00923	0.000925	42	-9.98	<.0001	Tukey-Kramer	<.0001
Fuel2	A		I		-0.01885	0.000925	42	-20.37	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		-0.00420	0.000925	42	-4.54	<.0001	Tukey-Kramer	0.0003
Fuel2	H		I		-0.00962	0.000925	42	-10.40	<.0001	Tukey-Kramer	<.0001
Fuel2	H		J		0.005034	0.000925	42	5.44	<.0001	Tukey-Kramer	<.0001
Fuel2	I		J		0.01465	0.000925	42	15.84	<.0001	Tukey-Kramer	<.0001
Test		FTP		UNI	-0.00126	0.000654	42	-1.93	0.0609	Tukey-Kramer	0.0609

Table 112: Test the Significance of the Fixed Effect – Fuel Type for FE3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	39	12.24	<.0001
Test	1	39	114.62	<.0001
Fuel2*Test	3	39	2.45	0.0778

Table 113: Least Squares Means

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		0.06273	15.94134
Fuel2	H		0.07358	13.59065
Fuel2	I		0.08439	11.84975
Fuel2	J		0.07126	14.03312
Test		FTP	0.05934	16.85204
Test		UNI	0.08664	11.54201

Table 114: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		-0.01086	0.003788	42	-2.87	0.0065	Tukey-Kramer	0.0315
Fuel2	A		I		-0.02167	0.003788	42	-5.72	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		-0.00853	0.003788	42	-2.25	0.0295	Tukey-Kramer	0.1258
Fuel2	H		I		-0.01081	0.003788	42	-2.85	0.0067	Tukey-Kramer	0.0325
Fuel2	H		J		0.002324	0.003788	42	0.61	0.5428	Tukey-Kramer	0.9272
Fuel2	I		J		0.01313	0.003788	42	3.47	0.0012	Tukey-Kramer	0.0065
Test		FTP		UNI	-0.02730	0.002678	42	-10.19	<.0001	Tukey-Kramer	<.0001

Table 115: Least Square Mean (LSM) Values for 1,3-Butadiene

Fuel	1,3-ButadieneW	
ANOVA p-value	0.0226	
	LSM (estimate)	**LSM (back transformed)**
A	1.5499	4.710999
H	1.9283	6.877808
I	0.9425	2.566389
J	2.3740	10.74027

Table 116: Mixed Model Analysis for 1,3-Butadiene Emissions Contrast Among Fuels

Fuel	**Fuel**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adj P**
A	H	-0.3784	0.4458	18	-0.85	0.4070	0.8304
A	I	0.6074	0.4458	18	1.36	0.1898	0.5373
A	J	-0.8241	0.4458	18	-1.85	0.0810	0.2841
H	I	0.9858	0.4241	18	2.32	0.0320	0.1294
H	J	-0.4457	0.4241	18	-1.05	0.3072	0.7226
I	J	-1.4315	0.4241	18	-3.38	0.0034	0.0162

Table 117: Least Square Mean (LSM) Values for Benzene

Fuel	BenzeneW	
ANOVA p-value	0.0043	
	LSM (estimate)	**LSM (back transformed)**
A	5.0728	159.6206
H	4.9271	137.9788
I	4.1517	63.54193
J	4.5103	90.9491

Table 118: Mixed Model Analysis for Benzene Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	0.1457	0.2454	18	0.59	0.5600	0.9326
A	I	0.9212	0.2336	18	3.94	0.0010	0.0048
A	J	0.5625	0.2336	18	2.41	0.0270	0.1112
H	I	0.7754	0.2454	18	3.16	0.0054	0.0254
H	J	0.4167	0.2454	18	1.70	0.1067	0.3534
I	J	-0.3587	0.2336	18	-1.54	0.1420	0.4381

Table 119: Least Square Mean (LSM) Values for Toluene

Fuel	TolueneW	
ANOVA p-value	<.0001	
	LSM (estimate)	**LSM (back transformed)**
A	5.1587	173.9382
H	5.0017	148.6657
I	4.0686	58.47504
J	3.0116	20.31989

Table 120: Mixed Model Analysis for Toluene Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	0.1570	0.2907	18	0.54	0.5958	0.9480
A	I	1.0901	0.2772	18	3.93	0.0010	0.0049
A	J	2.1471	0.2772	18	7.75	<.0001	<.0001
H	I	0.9331	0.2907	18	3.21	0.0049	0.0229
H	J	1.9901	0.2907	18	6.85	<.0001	<.0001
I	J	1.0570	0.2772	18	3.81	0.0013	0.0064

Table 121: Least Square Mean (LSM) Values for Ethylbenzene

Fuel	EthylbenzeneW	
ANOVA p-value	<.0001	
	LSM (estimate)	**LSM (back transformed)**
A	3.5063	32.32474
H	3.7743	42.567
I	2.0680	6.908989
J	2.1365	7.469742

Table 122: Mixed Model Analysis for Ethylbenzene Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	-0.2680	0.2448	18	-1.09	0.2880	0.6970
A	I	1.4384	0.2448	18	5.88	<.0001	<.0001
A	J	1.3699	0.2448	18	5.60	<.0001	0.0001
H	I	1.7064	0.2334	18	7.31	<.0001	<.0001
H	J	1.6379	0.2334	18	7.02	<.0001	<.0001
I	J	-0.06849	0.2334	18	-0.29	0.7725	0.9909

Table 123: Least Square Mean (LSM) Values for *m/p*-xylene

Fuel	*m/p*-xyleneW	
ANOVA p-value	<.0001	
	LSM (estimate)	**LSM (back transformed)**
A	4.4882	88.96117
H	3.9058	49.68982
I	2.6258	13.81562
J	3.1304	22.88313

Table 124: Mixed Model Analysis for *m/p*-xylene Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	0.5824	0.2602	18	2.24	0.0381	0.1506
A	I	1.8623	0.2602	18	7.16	<.0001	<.0001
A	J	1.3578	0.2602	18	5.22	<.0001	0.0003
H	I	1.2799	0.2481	18	5.16	<.0001	0.0004
H	J	0.7754	0.2481	18	3.13	0.0058	0.0272
I	J	-0.5046	0.2481	18	-2.03	0.0569	0.2126

Table 125: Least Square Mean (LSM) Values for *o*-xylene

Fuel	*o*-xyleneW	
ANOVA p-value	<.0001	
	LSM (estimate)	**LSM (back transformed)**
A	3.2754	26.4538
H	2.8876	17.95018
I	1.8151	6.14169
J	1.8752	6.522123

Table 126: Mixed Model Analysis for *o*-xylene Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	0.3879	0.2516	18	1.54	0.1406	0.4348
A	I	1.4604	0.2516	18	5.80	<.0001	<.0001
A	J	1.4002	0.2516	18	5.57	<.0001	0.0002
H	I	1.0725	0.2399	18	4.47	0.0003	0.0015
H	J	1.0123	0.2399	18	4.22	0.0005	0.0026
I	J	-0.06017	0.2399	18	-0.25	0.8048	0.9943

Table 127: Least Square Mean (LSM) Values for Formaldehyde

Fuel	Formaldehyde W	
ANOVA p-value	0.0500	
	LSM (estimate)	**LSM (back transformed)**
A	3.9778	53.39943
H	3.9558	52.23747
I	4.2625	70.98723
J	4.3541	77.79678

Table 128: Mixed Model Analysis for Formaldehyde Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	0.02199	0.1606	19	0.14	0.8925	0.9990
A	I	-0.2847	0.1606	19	-1.77	0.0923	0.3163
A	J	-0.3763	0.1606	19	-2.34	0.0302	0.1234
H	I	-0.3067	0.1606	19	-1.91	0.0714	0.2572
H	J	-0.3983	0.1606	19	-2.48	0.0227	0.0957
I	J	-0.09156	0.1606	19	-0.57	0.5753	0.9398

Table 129: Least Square Mean (LSM) Values for Acetaldehyde

Fuel	Acetaldehyde W	
ANOVA p-value	<.0001	
	LSM (estimate)	**LSM (back transformed)**
A	3.9813	53.58665
H	5.5501	257.2633
I	5.8981	364.3446
J	3.9930	54.2173

Table 130: Mixed Model Analysis for Acetaldehyde Emissions Contrast Among Fuels

Fuel	Fuel	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
A	H	-1.5687	0.1423	19	-11.03	<.0001	<.0001
A	I	-1.9167	0.1423	19	-13.47	<.0001	<.0001
A	J	-0.01162	0.1423	19	-0.08	0.9358	0.9998
H	I	-0.3480	0.1423	19	-2.45	0.0243	0.1019
H	J	1.5571	0.1423	19	10.95	<.0001	<.0001
I	J	1.9051	0.1423	19	13.39	<.0001	<.0001

Table 131: Test the Significance of the Fixed Effect – Fuel Type for Butyraldehyde

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	19	13.01	<.0001

Table 132: Least Square Mean

Least Squares Means			
Effect	**Fuel2**	**Estimate**	**Back transformed**
Fuel2	A	3.0796	20.7497
Fuel2	H	2.4256	10.30901
Fuel2	I	3.0589	20.30411
Fuel2	J	4.3290	74.86838

Table 133: Differences of Least Squares Means

Differences of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	0.6540	0.3125	19	2.09	0.0500	Tukey-Kramer	0.1912
Fuel2	A	I	0.02075	0.3125	19	0.07	0.9478	Tukey-Kramer	0.9999
Fuel2	A	J	-1.2494	0.3125	19	-4.00	0.0008	Tukey-Kramer	0.0039
Fuel2	H	I	-0.6333	0.3125	19	-2.03	0.0570	Tukey-Kramer	0.2135
Fuel2	H	J	-1.9034	0.3125	19	-6.09	<.0001	Tukey-Kramer	<.0001
Fuel2	I	J	-1.2702	0.3125	19	-4.06	0.0007	Tukey-Kramer	0.0034

Table 134: Test the Significance of the Fixed Effect – Fuel Type for PM Mass

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	37	1.61	0.2038
Test	1	37	5.49	0.0246
Fuel2*Test	3	37	3.08	0.0391

Table 135: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2*Test	A	FTP	0.6039	1.709239
Fuel2*Test	A	UNI	1.0111	2.628623
Fuel2*Test	H	FTP	0.5872	1.678944
Fuel2*Test	H	UNI	0.1434	1.034191
Fuel2*Test	I	FTP	0.9383	2.435633
Fuel2*Test	I	UNI	0.1781	1.074945
Fuel2*Test	J	FTP	0.8772	2.284159
Fuel2*Test	J	UNI	0.3317	1.273335

Table 136: Differences of Least square Means (Test FTP)

Differences of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	0.001564	0.3414	17	0.00	0.9964	Tukey-Kramer	1.0000
Fuel2	A	I	-0.3344	0.3559	17	-0.94	0.3605	Tukey-Kramer	0.7842
Fuel2	A	J	-0.2884	0.3414	17	-0.84	0.4100	Tukey-Kramer	0.8324
Fuel2	H	I	-0.3360	0.3414	17	-0.98	0.3389	Tukey-Kramer	0.7602
Fuel2	H	J	-0.2900	0.3249	17	-0.89	0.3845	Tukey-Kramer	0.8087
Fuel2	I	J	0.04599	0.3414	17	0.13	0.8944	Tukey-Kramer	0.9991

Table 137: Differences of Least Squares Means (Test UNI)

Differences of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	0.8676	0.2372	19	3.66	0.0017	Tukey-Kramer	0.0083
Fuel2	A	I	0.8330	0.2372	19	3.51	0.0023	Tukey-Kramer	0.0114
Fuel2	A	J	0.6793	0.2372	19	2.86	0.0099	Tukey-Kramer	0.0450
Fuel2	H	I	-0.03463	0.2372	19	-0.15	0.8855	Tukey-Kramer	0.9988
Fuel2	H	J	-0.1883	0.2372	19	-0.79	0.4371	Tukey-Kramer	0.8563
Fuel2	I	J	-0.1537	0.2372	19	-0.65	0.5248	Tukey-Kramer	0.9150

Table 138: Test the Significance of the Fixed Effect – Fuel Type for Weighted Particle Number

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	35	7.38	0.0006
Test	1	35	1.26	0.2685
Fuel2*Test	3	35	1.17	0.3341

Table 139: Least Square Mean

Least Squares Means			
Effect	**Fuel2**	**Estimate**	**Back transformed**
Fuel2	A	28.9838	3.87E+12
Fuel2	H	28.1851	1.74E+12
Fuel2	I	28.1207	1.63E+12
Fuel2	J	28.6859	2.87E+12

Table 140: Differences of Least Squares Means

Differences of Least Squares Means									
Effect	**Fuel2**	**Fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A	H	0.7987	0.2272	39	3.51	0.0011	Tukey-Kramer	0.0060
Fuel2	A	I	0.8631	0.2102	39	4.11	0.0002	Tukey-Kramer	0.0011
Fuel2	A	J	0.2979	0.2151	39	1.39	0.1738	Tukey-Kramer	0.5159
Fuel2	H	I	0.06440	0.2272	39	0.28	0.7783	Tukey-Kramer	0.9919
Fuel2	H	J	-0.5008	0.2320	39	-2.16	0.0371	Tukey-Kramer	0.1530
Fuel2	I	J	-0.5652	0.2151	39	-2.63	0.0122	Tukey-Kramer	0.0568

Table 141: Test the Significance of the Fixed Effect – Fuel Type for Particle Number1

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	35	7.92	0.0004
Test	1	35	25.09	<.0001
Fuel2*Test	3	35	0.15	0.9271

Table 142: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		29.9352	1E+13
Fuel2	H		29.2716	5.16E+12
Fuel2	I		28.8093	3.25E+12
Fuel2	J		29.6316	7.39E+12
Test		FTP	28.9601	3.78E+12
Test		UNI	29.8638	9.33E+12

Table 143: Differences of Least Square Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.6636	0.2624	35	2.53	0.0161	Tukey-Kramer	0.0726
Fuel2	A		I		1.1259	0.2419	35	4.65	<.0001	Tukey-Kramer	0.0003
Fuel2	A		J		0.3037	0.2480	35	1.22	0.2291	Tukey-Kramer	0.6160
Fuel2	H		I		0.4623	0.2624	35	1.76	0.0868	Tukey-Kramer	0.3084
Fuel2	H		J		-0.3600	0.2683	35	-1.34	0.1884	Tukey-Kramer	0.5435
Fuel2	I		J		-0.8223	0.2480	35	-3.32	0.0021	Tukey-Kramer	0.0110
Test		FTP		UNI	-0.9037	0.1804	35	-5.01	<.0001	Tukey-Kramer	<.0001

Table 144: Test the Significance of the Fixed Effect – Fuel Type for Particle Number2

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	35	4.20	0.0122
Test	1	35	6.80	0.0133
Fuel2*Test	3	35	0.92	0.4406

Table 145: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		28.9307	3.67E+12
Fuel2	H		28.1322	1.65E+12
Fuel2	I		28.0756	1.56E+12
Fuel2	J		28.6077	2.66E+12
Test		FTP	28.7016	2.92E+12
Test		UNI	28.1715	1.72E+12

Table 146: Differences of Least Square Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.7985	0.2956	35	2.70	0.0106	Tukey-Kramer	0.0495
Fuel2	A		I		0.8551	0.2725	35	3.14	0.0034	Tukey-Kramer	0.0173
Fuel2	A		J		0.3230	0.2794	35	1.16	0.2555	Tukey-Kramer	0.6580
Fuel2	H		I		0.05663	0.2956	35	0.19	0.8492	Tukey-Kramer	0.9975
Fuel2	H		J		-0.4755	0.3023	35	-1.57	0.1247	Tukey-Kramer	0.4067
Fuel2	I		J		-0.5321	0.2794	35	-1.90	0.0651	Tukey-Kramer	0.2447
Test		FTP		UNI	0.5301	0.2032	35	2.61	0.0133	Tukey-Kramer	0.0133

Table 147: Test the Significance of the Fixed Effect – Fuel Type for Particle Number3

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Fuel2	3	35	11.83	<.0001
Test	1	35	8.14	0.0072
Fuel2*Test	3	35	1.24	0.3111

Table 148: Least Square Mean

Least Squares Means				
Effect	**Fuel2**	**Test**	**Estimate**	**Back transformed**
Fuel2	A		27.9624	1.39E+12
Fuel2	H		27.1359	6.09E+11
Fuel2	I		27.0615	5.66E+11
Fuel2	J		27.2411	6.77E+11
Test		FTP	27.1714	6.32E+11
Test		UNI	27.5291	9.03E+11

Table 149: Differences of Least Squares Means

Differences of Least Squares Means											
Effect	**Fuel2**	**Test**	**Fuel2**	**Test**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
Fuel2	A		H		0.8265	0.1824	35	4.53	<.0001	Tukey-Kramer	0.0004
Fuel2	A		I		0.9009	0.1681	35	5.36	<.0001	Tukey-Kramer	<.0001
Fuel2	A		J		0.7213	0.1724	35	4.18	0.0002	Tukey-Kramer	0.0010
Fuel2	H		I		0.07438	0.1824	35	0.41	0.6858	Tukey-Kramer	0.9767
Fuel2	H		J		-0.1052	0.1865	35	-0.56	0.5763	Tukey-Kramer	0.9420
Fuel2	I		J		-0.1796	0.1724	35	-1.04	0.3047	Tukey-Kramer	0.7264
Test		FTP		UNI	-0.3577	0.1254	35	-2.85	0.0072	Tukey-Kramer	0.0072